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AN EXPLANATION

OF THE

GNOMONIC PROJECTION

OF

THE SPHERE;

D OF SUCH POINTS OF ASTRONOMY AS ARE MOST NECESSARY IN THE USE OF ASTRONOMICAL MAPS.

BEING

A DESCRIPTION OF THE CONSTRUCTION AND USE OF THE LARGER AND SMALLER

MAPS OF THE STARS;

AS ALSO OF THE

SIX MAPS OF THE EARTH.

BY

AUGUSTUS DE MORGAN,

OF TRIN. COLL., CAMB., SECRETARY OF THE ROYAL ASTR. SOC.

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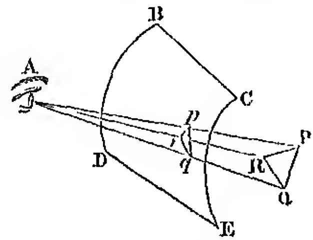
ADVERTISEMENT.

'HIS Tieatise, though particulaily intended for those who use ither of the maps mentioued in the title-page, will, I hope, be ound usefnl to all who wish to acquire a distinct idea of the connexion between piojections in geneial, and the surface of the here which they repiesent. The leading piinciples deiived from n accurate consideration of any one instance, aie those which pply to eveiy other hitheito used, with the exception only of what called Meicatoi's Piojection. But of all the methods in question, should decidedly prefei the Gnomonic Piojection foi any purpose f geneial instruction, on account of its superioi simplicity, and ie ease with which the tiansition may be made from the sphere its inclosing cube.

Simple as a globe may be in its piinciple, theie aie many icilities affoided by a map, and on the othei hand, there are ome points in which the foimer has decided advantages over the ttei. A map may be considered either as a catalogue for the iactical astronomei, oi as a pictuie of the heavens for a leainer n the former point of view, it is of little consequence what projection is employed · in the lattei, the piimary propeity of the inomonic Piojection, namely, that three staıs which are in a line i the appaient heavens, aie also in a line in the map, renders it, which would oblige us to follow it with one telescope, and alter the angle which the two make with one another.

If we imagine a transparent surface of glass, of any form whatever, to be interposed between the eye and the objects which are to be pictured, and if straight lines be drawn through the various points of any object, all meeting at the eye, which may represent rays of light, the points at which these rays intersect the glass will together mark on the glass the picture of the object chosen. This is represented in the following diagram, where A is the position of the eye, B C D E a part of the map or picture, and P Q R a triangle to be represented. The space *p q r* is that through some point of which every ray of light coming from any point of the triangle must pass, in order to reach the eye; so that if the part *p q r* were opaque, the triangle could not be seen. It is the object of a *map*, simply to mark out this space; of a *picture*, to mark it out in such a way, by colouring and shading, that the rays which come from the various points of *p q r* shall resemble in colour and brilliancy those which would pass through *p q r*, if the transparency were restored and the object allowed to be seen.

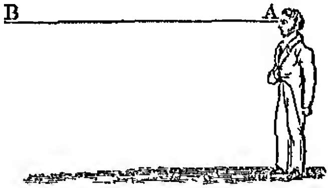


Let us now suppose a spectator situated at any point of the earth. So long as he looks at the fixed stars only, it is indifferent in what part of her orbit the earth may be, since the distance of the fixed stars is so great, that there is no apparent change of place arising out of the motion of the earth in her orbit. Thus in travelling, objects which are near to us change their directions perceptibly in a very short time; and we leave behind us the things which shortly before were at our right or left hands. This sort of change is perceived in instrumental observation with regard to the planets, which are sufficiently near to show the earth's change of place as well as their own. But, just as in the former case it may be hours or days before the direction in which we see a distant hill is perceptibly altered, or as the seamen say, before its *bearing* is changed; so on the heavens, the whole yearly track of the earth does not enclose a space which is perceptible from the nearest fixed star, so that the position of the latter will not be sensibly altered by the orbital motion of the earth. The reader must attend to this point, because to this it is owing that we do not want different maps of the stars for different periods of the year.

If a glass globe of considerable dimensions were constructed around the spectator, of which his eye was in the centre, and if we imagine, for the sake of illustration, that the spectator is not on the earth, but in void space, where he can see the whole of the heavens, we may conceive a number of dark spots to be placed upon this globe, in such a way as to hide from him the several stars which before were visible Here would be a picture of the relative positions of the stars, which would be a lasting one, since the apparent change of place arising out of the diurnal motion of the earth is not taken into account, the spectator being fixed. If, however, we imagine the apparent revolution of the stars caused by the last-mentioned motion to be real, and to carry all the stars round the spectator in twenty-four hours, the globe may be supposed to turn in the same time, and in the same direction, by which means each spot will continue to keep the same star out of view which it did at first

The visible part of the heavens has the appearance of half such a globe; for since we form no idea of the relative distances of the different stars from ourselves, the latter seem like bright spots all situated at the same distance from us, at least it requires no effort of imagination to suppose them such. They give us, therefore, the idea of being placed upon an immense sphere, of which the glass globe just alluded to is a small copy. We see from many terrestrial appearances, that when distances become considerable, we lose the power of distinguishing one from another: thus when a large part of the horizon is bounded by a chain of hills, very far from us, it seems as if they were arranged in a part of a circle, though perhaps they may be in a straight line interrupted by continued and irregular variations

This circular form of the horizon is a proof of the tendency to estimate those distances as equal, between which, from their magnitude, we have lost the power of discriminating. However irregular the ground may be, the boundary of the view, if in any degree extended in all directions, is circular. As this phenomenon is cited in many popular works on astronomy as a proof of the rotundity of the earth, we will call attention to the fact that it would still remain, if the earth were a plane, indefinitely extended on every side. For, such being the case, suppose a spectator at sea, with an open view in all directions; there would still be an apparent boundary, since all above the line A B would be sky, and all below it water. There would therefore be in every direction a visible line in which the sky and water meet, which would appear at the same distance in every direction, and would assume the



form of a circle, *at the height of the eye*. The proof of the rotundity of the earth, from the appearance of the horizon at sea, ought to be derived from the line in which the sky and water meet *not* being of the same height as the eye, which appears in the following diagram to be the property of a spherical or other round surface. This phenomenon is very clearly visible when the horizon is viewed from the top of a high hill.

From the actual survey of the heavens, the stars were divided into groups, which were fancifully likened to figures of men and animals, before any globes or maps were constructed. Thus the astronomer had certain fixed notions of the positions which the constellations occupied relatively to one another, and to himself, that is, to the centre of the apparent celestial sphere. The stars were distinguished from one another by the positions they occupied upon the body of the constellation to which they belonged, one was in the right arm, another in the left, a third in the leg, and so on. The formation of artificial globes involved a difficulty, as the spectator of the globe was not in the same position relatively to the pictured constellations as that in which he stood to the apparent celestial sphere; being on the outside, and not at the centre. If we conceive an artist, painting the globe in the interior, according to his own notions of the relative position of the constellations, another person viewing the figures from the exterior, through the glass, would see them all reversed; that is, the hand which the interior observer would call the *right*, is the *left* in the opinion of the exterior observer. The same effect is produced by looking through a picture from the back. Most persons must be aware of the manner in which it is necessary to arrange the letters in the printer's composing-stick, in order that the impression may be direct, or from left to right. If the types could be arranged as follows,

Maps of the Stars;

the impression taken from them would be the following,

Maps of the Stars;

and *vice versâ;* so that types set up in the second way exhibit an impression like the first. The reason why the printers' types cannot be set up in the first position, is that they cannot be completely reversed, since in that case they would only present the unlettered end of the metal to the paper unless stamped at both ends. The partial reversal that the common types would bear, would simply amount to writing the sentence backwards, and upsidedown, as follows,

Maps of the Stars;

this is the appearance presented, not to a spectator outside the globe, but to one who stands upsidedown inside the globe.

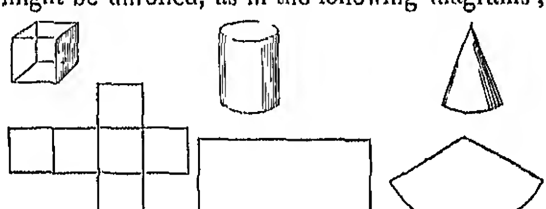
If the first arrangement were made on thin paper, the second would appear on looking at it through the paper, and the same alteration takes place when that which has been written or drawn on the inside of a transparent globe, is looked at from the outside. A spectator on the outside sees the figures as he ought to draw them on wood or copper, in order that the impression may represent the appearances presented to a spectator on the inside.

Let us now suppose that the artist in the interior, instead of drawing figures upon the globe, forms thin and flexible statues, in which the front and back, or the two sides if the figure is placed sideways, are perfectly formed, the thickness only being diminished. These he fastens on the interior of the globe, with the fronts towards himself. Hence where he sees the front of a figure, the spectator on the outside will see the back; where one sees the right hand side, the other will see the left, both will see the same outline, but differently filled up in the two cases, as in the following picture, which exhibits the appearance of a figure from the interior and exterior.

There will now be no confusion between the right hand and the left, since both will fix upon the same hand when asked for either; but those stars which to the spectator in the interior appear in the breast of a figure, will to a spectator at the outside appear in the back. We shall hereafter resume this subject in discussing the rea-

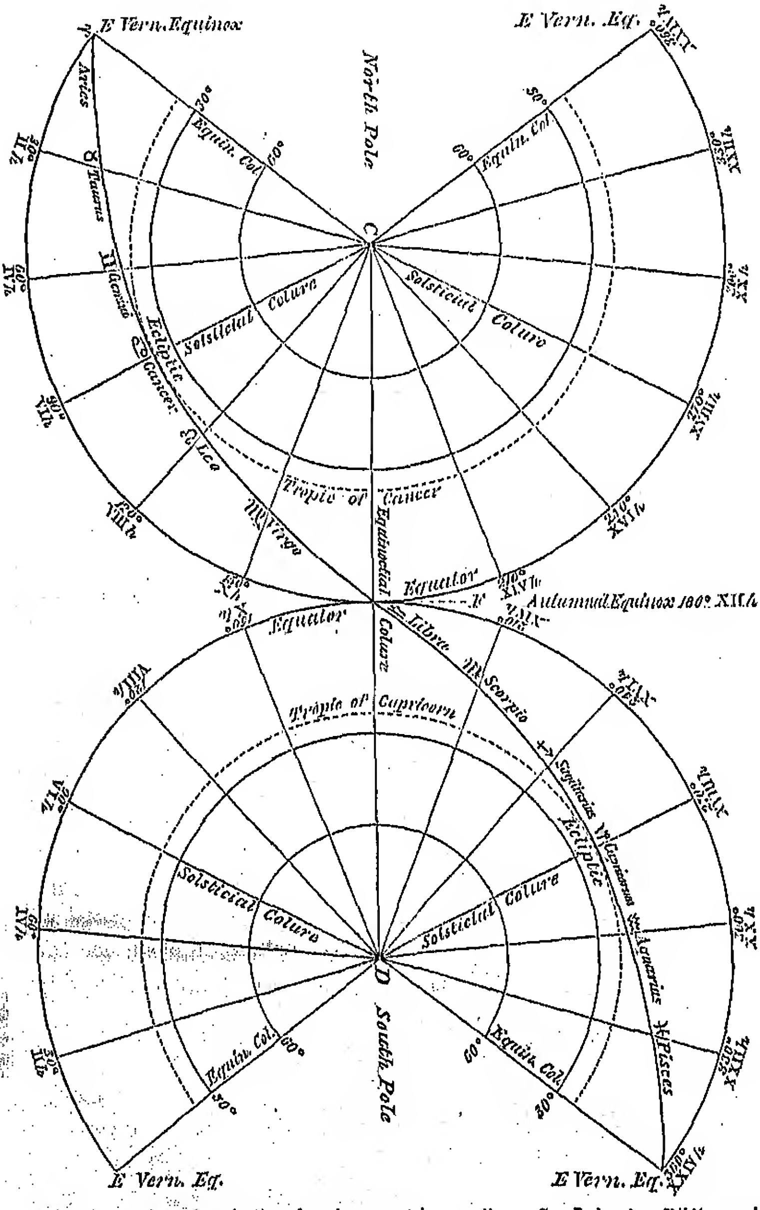
sons which have been thought sufficient for the adoption of the scheme followed in the maps we are describing

The globe having been thus obtained, and the position of the spectator settled, we come to the definition and construction of a map of the globe. By the word map is generally understood a representation of part of a curved surface on a plane, or flat surface. If we wanted a map of a cone or cylinder, the surfaces of which admit of being unrolled without the relative position of any points on the surface being altered, that is without any expansion, contraction, or tearing, a perfect map would be obtained by simply unrolling the surface But a sphere has not this property of *development*, and whatever contrivance we may employ, the representation of a sphere upon a plane must produce some *distortion;* that is, stars which are at equal distances on the globe, cannot always be placed at equal distances on the map. This is however an objection only when a map is considered as a perfect picture or resemblance of the whole heavens, but none whatever when we consider a map as no more than a method of registering the different stars and nebulæ, which shall preserve contiguous portions of the heavens, when not very large, in something like their relative positions It is sufficient for the purpose of registry, to have a plane or planes, so connected with the sphere by a simple mathematical law, that every point of the globe has one point, and no more, corresponding to it upon the planes; and for the purposes of general similitude, it is enough that objects which are very near upon the globe are very near upon the map, the proportions of distance upon the latter not very much differing from those upon the former: for example, if the star A upon the globe is twice as far from B as from C, it is sufficient that on the map the distance of A from B does not differ much from twice the distance of A from C. Rejecting the latter condition, we may conceive various ways of constructing a map either upon planes or other surfaces, which shall answer the principal condition of having one point and no more on the map, corresponding to each point upon the globe. For illustration, conceive the stars, constellations, &c., to be drawn upon a globe with ink, which, as soon as it is laid on any point, sinks directly to the centre, without spreading in any other direction; so that each point, so soon as it is marked, is connected with the centre by a dark line. Let parts of the globe be now cut away regularly or irregularly, with this condition only, that the centre is never to be laid open, and no excavation is to be made which shall, after one of the dark lines has been divided from the centre, allow any higher part of that line to continue in the piece which contains the centre. In this case, whatever may be the form of the remaining piece, it is, theoretically speaking, as complete a representation of the heavens as the globe itself: for though any star be cut away, some other point of the black line which ran from it to the centre will be laid open, and the star will not be lost. If the sphere were placed upon a turning lathe, and turned into another and smaller sphere with the same centre, there would be no *distortion*, since all figures and distances would be lessened in the same proportion. This would hardly be a map, in the common sense of the word, for it could not be unrolled and laid upon a plane, the sphere, as already explained, not being *developable*. But if a cone or cylinder, or a cube or other surface composed entirely of plane faces, were cut out of the sphere, the surface thus obtained might be unrolled, as in the following diagrams; in which



the cube forms six squares placed together, the cylinder a rectangle, and the cone a sector of a circle.

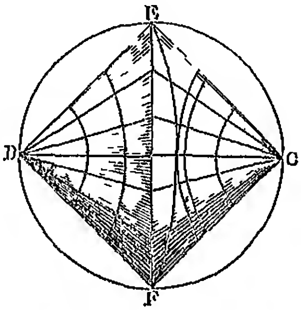
We now exhibit one sort of map*, which we have purposely



* This species of projection has been put in practice. See Lalande, *Bibliographie Astronomique*, pp. 352 and 561.

chosen because it is not much like any of those which are most commonly seen. Differing entirely from a common picture in principle, and being altogether unlike any representation of a globe, it will the better illustrate our definition that any figure will serve for a map, which has a point corresponding to every point on the globe

It consists of two circular sectors, E C E F E and E D E F E, each containing more than a semicircle, or about 254½°. Each of these sectors is a developed cone, and the cones may be restored by cutting out the sectors, and bringing together the pairs of lines marked D E, D E, and C E, C E The two cones thus formed will have the diameters of their bases double of their heights, and when put together base to base, will form a double cone or spindle, having the distance between its opposite vertices (that is, twice the height of either cone) equal to the diameter of the common base If we suppose a sphere made by the revolution of the circle C E D F about its diameter C D, such a spindle-shaped surface will be

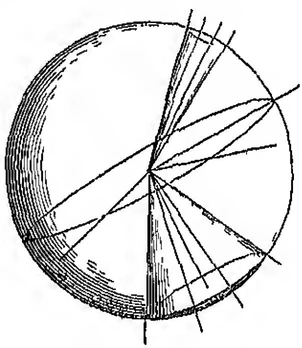


described by the periphery or outline of the square C D E F We may conceive the stars represented on the globe as already described, and the sphere then cut away, all except the double cone, which will, on our preceding suppositions, when unrolled, exhibit the map we have chosen The only points which are twice represented, are those on C E, C E, and D E, D E, as these lines are made to coincide when the cones are formed.

We recommend the reader who is not used to such considerations, not to leave this diagram until he can well account for the various appearances exhibited on the map, and reconcile them with the globe. As this construction is not the one which we have to explain, we will not dwell upon it further, except to point out the distortion which must take place Looking at CE, we see that the length from 30° to 60° is much less than that from 0° to 30°, or from 60° to 90°, whereas on the globe these are equal lengths.

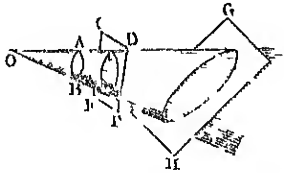
Abandoning the illustration hitherto used, we will now suppose the reader able to carry in his mind the idea of a sphere with the great and small circles drawn on it, together with the stars and constellations, and having straight lines drawn from the centre through every star, and through every point in the great and small circles. These lines must be supposed to be produced beyond the surface of the sphere as far as may be necessary. A *great* circle of the sphere is one which passes through the centre, and divides the whole into two equal hemispheres Any other circle is called a *small* circle These names are certainly not very expressive, since a small circle may be as nearly equal in magnitude as we please to a great circle. It would be better, perhaps, to call them *centric* and *excentric* circles; but custom has sanctioned the preceding appellations

Let us call the line drawn through any point of the sphere from the centre, the *projecting line* of that point A great circle, with all its projecting lines, forms a plane; a small circle, with all its pro-

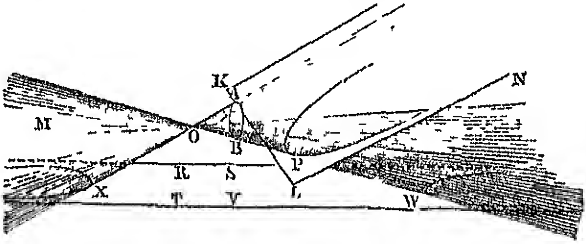


jecting lines, a cone. If any plane be placed outside a sphere, so as to be cut by the projecting lines coming from any part of the sphere, a map of that part of the sphere will be formed upon the plane, and the point of the map which corresponds to any star, is the point in which the projecting line of the star cuts the plane. If the globe were transparent, and the stars placed upon it opaque, and if a small lamp were placed in the centre, the shadows of the several stars would fall upon the corresponding points of the map.

The line or point on the map which represents any line or point on the globe, is called its *projection*. The projection of a great circle is a straight line, since all its projecting lines are in one plane, and a plane cuts a plane in a straight line. The form of the projection of a *small* circle depends upon its position relatively to the centre, and to the map. To determine the different forms which this projection may assume, we must recollect that the projecting lines which pass through the centre of the globe, and the various points in the circumference of a small circle, form a cone. If we, therefore, let the circle remain in its place, and move the plane in which the map is to be drawn, the various figures in which the moving plane of the map cuts the cone will be those of which we are in search, namely, all the possible projections of the small circle.

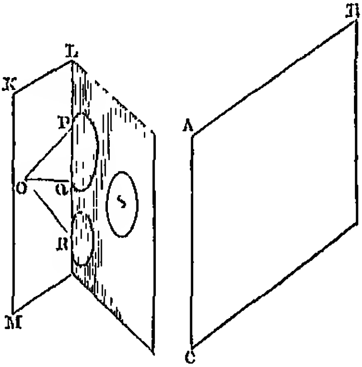


Let O be the centre of the globe, and A B the small circle which is to be represented on the map. The various lines of the conical surface O A B are therefore those which convey, so to speak, each point of the circle to its appropriate place on the map. If the latter be held parallel to the position of the small circle, as at C D E F, the representation of the circle will be another circle, differing from the former in size. If the map be held obliquely to the circle, as at G H, but still in such a position as to cut the cone completely through, the representation will be a flattened figure, called, in geometry, an *ellipse*. To get a clear idea of the other figures, we must



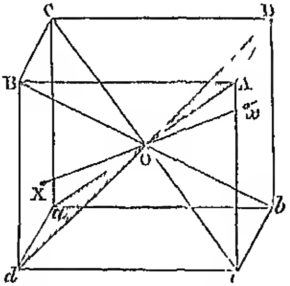
make another conical surface O M, behind the surface O A B, by lengthening all the projecting lines in the cone O A B, backwards towards the left. If the map be so held, as at K L N, that it shall never completely pass through the cone O A B, but yet at the same time shall never cut the opposite cone O M, though ever so far lengthened either way, the representation of the circle will be a figure, which, though resembling an oval at or near the point P, spreads out without limit on both sides of it, so that it has no point opposite to P. The point A has therefore no representative upon the map, for O A, being parallel to the plane K L N, will never meet it. The figure in which K L N cuts the cone in this case, is called a *parabola*. Now let the map be held still more obliquely to the circle, as at R S T V, so that having cut the cone at W, it also cuts the opposite cone at X, instead of passing through the other side of the first cone, as in H G, or remaining always equidistant from the opposite parts of both cones, as in K N. The representation of the circle will therefore consist of two figures proceeding from W and X, the first towards the right, the second towards the left. Through O conceive two lines, O Y and O Z, to be drawn, parallel to the plane R S T V, and cutting the circle in Z and Y. It is evident that all the figure to the right of W is the representation of so much of the circle as falls below Z and Y, or is contained in the arc Z B Y, while the figure to the left of X represents the arc Z A Y. For if from any point of the circle which is above Z Y, we draw a line through O, it will fall towards the left of the plane R S T V, beyond X. This double figure is called an *hyperbola*, of which the two separate parts containing W and X are called the *branches*. We shall not have occasion to consider more than one branch of an hyperbola, namely, that in which the point represented falls between its projection and the centre; that is, we shall only want the part which contains W, and corresponds to the lower arc Z B Y in our figure.

The general conclusion is as follows:—Let a point, a circle, and a plane, be all situated in space, and let a straight line, which always passes through the point, and runs along the circumference of the circle, be produced in both directions, till it meets the plane either on one side of the point or the other, thus tracing out a curve on the plane, while it moves round the circle. If the straight line always meets the plane, that is, never becomes parallel to it, an ellipse is marked out on the plane. If the straight line is parallel to the plane in one position, *and one position only*, it traces out a parabola, and if it becomes parallel to the plane in two different positions, it traces out an *hyperbola.* The curve is called the *projection* of the circle upon the plane, the point is called the *pole* of projection, and the plane, the *plane of projection.*



The simplest way of applying the preceding rule is as follows: Let O be the pole of projection, A B C the plane of projection, and through O draw a plane K L M parallel to A B C The planes are to be considered as indefinitely extended in all directions It is a theorem in geometry, that all the lines which can be drawn through O, parallel to the plane A B C, lie entirely in the plane K L M, and the converse, that is, if a line passing through O lie upon K L M, it will never meet A B C, while, if it do not lie upon K L M, it will meet A B C, if produced far enough. If then a circle cut the plane K L M, meeting it therefore in two points P and Q, there are two lines which can be drawn through O, and the circumference, parallel to the plane A B C, namely O P and O Q; if the circle only rests upon the plane K L M, or touches it in one point only, as R, there is only one line which can be drawn through O and the circumference parallel to the plane A B C, namely, O R; while if the circle be entirely off the plane K L M S, as S, no line can be drawn through O and the circumference parallel to A B C. In the first case, the projection of the circle upon the plane A B C from the pole O is an hyperbola; in the second, a parabola; in the third, an ellipse. Therefore, draw a plane through the pole of projection parallel to the map or plane of projection: if this plane cuts the circle, the projection is an hyperbola; if the circle only meets the second plane, the projection is a parabola; if the circle does not meet the second plane, the projection is an ellipse.

We now come to the description of the method which has been employed in the maps to be explained. The pole of projection is the centre of the globe The maps are planes, six in number, touching the globe so as to form the circumscribed cube. The figure called a



cube, which is that of a die, or of a box, the length, breadth, and depth of which are equal, is bounded by six equal square surfaces, which are opposite, two and two. It has twelve sides or edges, and eight* corners or angles Each side (as C *a*) has another side (*c* A) opposite and parallel to it, and two other sides (B *d* and D *b*) adjacent and parallel. In future, we shall denote four of the angles or corners by the letters A, B, C, D, and the opposite angles by the small letters *a*, *b*, *c*, *d*. Thus to find, mechanically, the side, surface, or angle which is opposite to any given one, change large letters into small, and small letters into large For instance, the corner opposite to A is *a*, the side opposite to B *d* is *b* D, and the surface opposite to B C *a d* is *b c* A D.

The cube has a centre, in which the lines A *a*, B *b*, C *c*, and D *d*, meet, and this centre, which we call O, is also the centre of the sphere, when the latter is placed inside the cube The point O is equally distant from every corner, though, owing to the perspective,

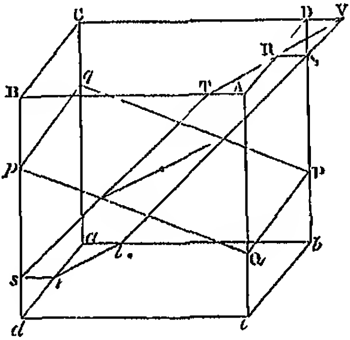
* The number of surfaces and solid angles in a solid bounded by planes will always together exceed the number of edges by *two*: thus in the cube, there are six surfaces, eight angles and twelve edges, and

$$6 + 8 = 12 + 2.$$

In a pyramid, there are four surfaces, four angles and six edges.

this does not appear to be so in the figure. Any line drawn through the centre cuts two opposite surfaces in points which are situated in the same parts of each. Thus the line X O *x* drawn through O cuts B C *a d* in X, and *b c* A D in *x*; and if the square B C *a d* were laid upon *b c* A D, so that *d*, B, and C should coincide with D, *b*, and *c*, X would coincide with *x*. The line X O *x* is also bisected in O

A plane passing through the centre O, and cutting the cube, may



pass through four of the faces, not meeting the other two, as P Q *p q*, or may cut all the six faces, as T R S *t r s*. In the first case, the intersection of the plane with the faces of the cube is a parallelogram; thus P Q is parallel to *p q*, and P *q* to *p* Q. The rest of this figure may be easily found, when one side only is known. Suppose, for example, *p* Q remains, and the other sides are rubbed out To restore P *q*, we go to the opposite map*, and finding the points D and C opposite to *d* and *c*, we take D P and C *q* respectively equal to *dp* and *c* Q. The points P and *q* being thus found, we join *p* and *q*, *q* and P, and P and Q. In the second case, where the plane cuts the cube in all six maps, the figure T R S *t r s* is a *hexagon*, or six-sided figure, with its opposite sides T R and *t r* parallel and equal, as also R S and *r s*, and T *s* and *t* S. Each side cuts off a corner from the map in which it is found, instead of passing through opposite edges

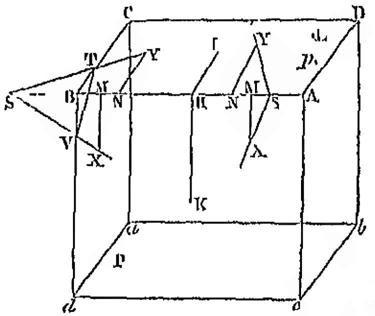
Supposing all the sides of this figure to be rubbed out, except T R, it is not so obvious how to replace them. We can immediately lay down *t r*, by taking *a t* equal to A T, and *ar* equal to A R, but

* This word is here introduced, as the six faces of the cube are the six maps to be explained.

before the section can be completed, we must find either S or *s*. Having found *t*, as just described, lengthen T R and C D till they meet in V Join V and *t*, meeting D *b* in S, which is the point required, and *t* S one of the remaining sides But this obliges us to travel out of the map, and perhaps beyond the limits of the paper. The following arithmetical method is preferable Suppose, for example, that each side of the map is twelve inches, and that A T is three inches, and A R five inches

Multiply the whole side A D	12 inches,
by what is left after taking away A R,	7
and by A T	3
which gives	252
Multiply each of the two A R and A T, by the remainder arising from subtracting the other from A D,	$5 \times 9 = 45$ $3 \times 7 = 21$
and add the products, which gives	66

Divide the first by the second, which gives D S $= 3\frac{9}{11}$ inches, or a little more than $3\frac{8}{10}$ inches This is also the length of *d s*, whence all the points of the hexagon are determined.



It remains to lay down the section when no *side* of it is given, but one *point* only in each of two different maps When the two points are in *opposite* maps, as in A B C D and *a b c d*, let them be E and P. On A B C D find *p* the opposite point to P, then the line *p* E produced to meet the sides, will be one of the sides of the section required; to complete which one of the preceding rules must be applied When the points are on adjacent maps, as on A B C D and A B, *c d*, let X and Y be the points, and X S Y a part of the section which passes through them and the centre. Draw X M and Y N perpendicular to the common side A B, bisect A B in H, and let L and K be the centres of the maps in question, whence H K or H L is half the side of the cube. Measure H N and N Y, H M and M X, and also H K or H L, the half-side of the cube. Form the four following products.

(1.) H M multiplied by N Y.

(2.) H N multiplied by M X.

(3.) The sum of M X and N Y multiplied by H K.

(4.) N Y multiplied by M X.

The length of H S and its direction may now be found as follows:

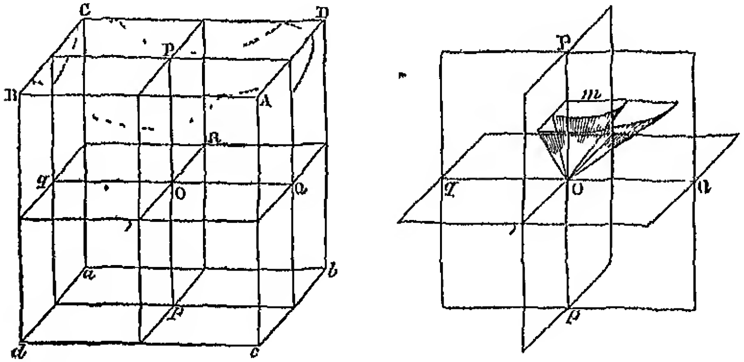
1. When N and M fall on the same side of H. Add together the products (1) and (2), multiply by H K, and divide by the difference of the products (3) and (4). The quotient is H S.

When it happens that H S is greater than H A or H B, as on the left side of the figure, T may be determined as follows: Find S B and S N, by subtracting H B and H N from H S just found. Multiply S B by Y N, and divide by S N. The answer is B T, and B V may be found by proceeding in the same manner with M X, and S M.

2. When M and N fall on different sides of H, take the difference of the products (1) and (2), multiply by H K, and divide by the difference of the products (3) and (4). The quotient is H S, which must fall on the same side of H as N, if the *greater* of the products (1) and (2) contains H N, or as M, if the greater product contains H M.

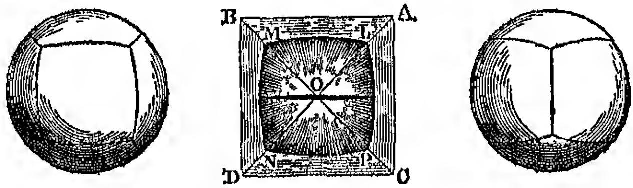
We should recommend the reader who wishes to get a clear idea of these and similar processes, to provide himself with a cube of soft wood, of about three inches in height, and to lay down several sections by the preceding rules. A common foot ruler will serve for the measurements, which may be made correctly enough for every practical purpose to twentieths of inches.

We now proceed to consider in what way a cone, whose vertex is at the centre of the cube, will intersect the several maps. We may see from page 13, that if a circle be placed inside the cube, which does not pass through its centre, the projection, if any, upon each single face of the cube will be the whole or part of an ellipse, or part of a parabola or hyperbola. Imagine a cubical room, in the centre of which a small lamp is placed, while an opaque circle is moved into various positions, throwing a well-defined shadow upon the walls or ceiling, or both. If the shadow be thrown entirely upon one wall, or upon the ceiling, it is an ellipse; for the ellipse is the only one of the three figures which is bounded, or contained in a finite space. But the shadow may be thrown partly on the wall or walls, and partly on the ceiling, so as to throw a part of one ellipse on the ceiling, and a part of another on the wall; or a part of an ellipse on the ceiling, and of an hyperbola on the wall, and so on. The rule given in page 13 will distinguish the cases immediately. Draw through the centre of the cube (the pole of projection), planes parallel to its several faces (the planes of projection), as in the following diagram; the left hand figure of which represents the cube with the planes



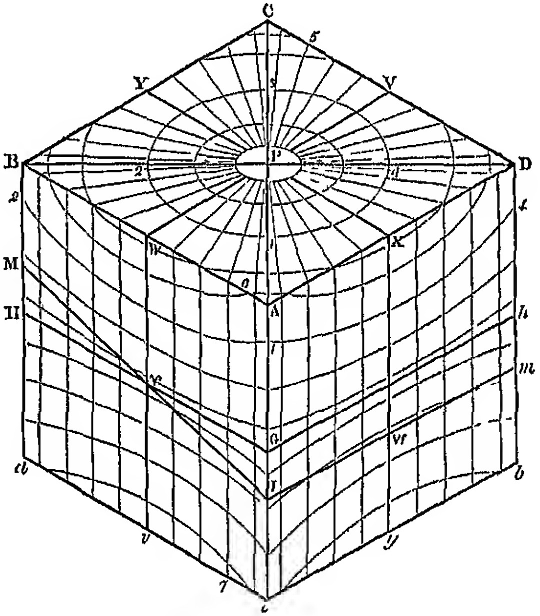
drawn inside it, and the right hand the planes by themselves. To take an instance, there is a circle of which we see the part *m*. It does not cut the central plane Q *q* R *r*, and therefore the projection of the circle on A B C D is an ellipse, or the part of it which falls on A B C D is part of an ellipse. In this case we ought to say the projection is itself a circle, because the circle *m* is parallel to the plane A B C D. But the term *ellipse* includes circle, because the circle is itself a particular species of ellipse. In the case of *m* as drawn in the figure, the projection is completely thrown on A B C D, because the cone drawn through O and the circle *m* passes out from the cube through A B C D before it has widened enough to meet the other faces. But if the circle *m* be increased, (as seen in the figure,) some part of the projection may be thrown on the sides, as in the left-hand figure, and the parts of it which *lap over* will not be parts of ellipses, but of hyperbolas, because the circle *m* cuts the central planes which are parallel to the lateral faces in question. By increasing the circle *m* still more, it will soon happen that none of the projection is contained in A B C D, but is thrown entirely on the four lateral maps, where it will appear as four arcs of hyperbolas. All three cases are distinctly shown in the figure of page 20, over leaf.

Let us now suppose a sphere, whose diameter is equal to A B, to be placed inside the cube, with its centre at O. It will therefore rest upon the cube at *p*, and will besides touch it in P, Q, *q*, R, and *r*. The various stars and constellations may now be projected upon the cube by right lines drawn through the centre O. There is no need to project the six points P, *p*, Q, *q*, R, and *r*, since they are both upon the sphere and the cube; and if through any other point of the sphere we draw a straight line from O, this line will meet the cube in some one or other of the six faces, and we then know to what map, and to what part of it, the star which is at that point of the globe must be referred. Each face of the cube receives the representation of a sixth part of the sphere, the form of which will be better understood from the following diagrams.



In the middle figure, O is the centre of the cube and sphere, and is the vertex of a pyramid, of which A B C D, a face of the cube, is the base. This pyramid contains a part of the sphere, and separates it from the rest. A B is the projection of L M, A C of L P, C D of P N, and D B of N M. The arcs N M, &c., are each about 70½° of the whole circumference, and the arc which extends from corner to corner is what remains of 180° or 109½°. The arc which runs through the middle of the map is 90°. The visible hemisphere on the left contains the portion which corresponds to one complete map, surrounded by the halves of the four contiguous maps: the invisible hemisphere on the other side contains the remaining halves of the four latter, together with the sixth map, which completes the whole sphere. The visible part of the globe on the right contains two complete maps, and the halves of two others.

Returning to the figure in page 18, the globe of the heavens is so placed within the cube, that P is the north pole, and p the south pole. Hence Q R q r is the representation of the equator. This will remain if we suppose the globe to turn inside the cube on the axis Pp; we stop it when the *equinoxes*, or points in which the ecliptic meets the equator, have come to R and r. Hence the poles, the projections of the equator and ecliptic, together with those of the circles of right ascension and declination, will assume the following form, of which the visible half only is drawn.



Returning to a preceding illustration, if we were to suppose every particle of ink laid upon this cube to sink direct to the centre, leaving a dark line to mark its progress, and if the solid were then placed upon a lathe, with P and its opposite point p (not seen) for pivots of rotation, and then turned into a sphere, the latter would be marked like a common globe as follows P and *p* would be the poles, G H *g h* would leave the equator on the globe, and L M *l m* the ecliptic. V W *v w* would become the equinoctial colure, and X Y *x y* the solstitial colure The lines marked 1 2 3 4, which are circles on the higher map, and parts of hyperbolas on the lateral maps, will all become circles of declination. Again, 5 P 6 7 8, and all similar sections of the cube, together with C A *c a*, D B *d b*, and X Y *x y*, V W *v w* already mentioned, will become circles of right ascension or horary circles.

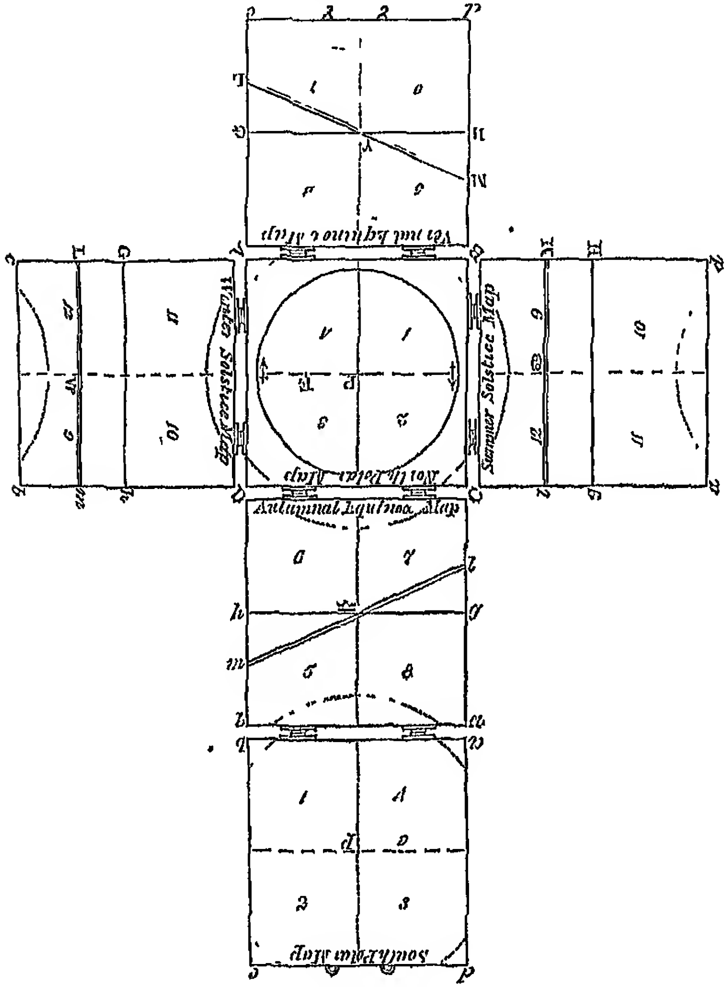
Before supposing the maps to be separated, it will be convenient to have some distinct name for each These at the top and bottom we shall call the *north polar* and *south polar* maps, from the poles which they contain. The letters at the corners of these will be A B C D and *a b c d*. Each of the lateral maps contains one of the principal points of the ecliptic, from which it may take its name The denominations will therefore be as follows

A B C D	North Polar Map
A B *c d*	Vernal Equinox Map
B C *d a*	Summer Solstice Map
C D *a b*	Autumnal Equinox Map
D A *b c*	Winter Solstice Map
a b c d	South Polar Map

No difficulty will arise from our using letters not seen in the diagram, if it be recollected that the small letter corresponding to any great letter is always on the point of the cube directly opposite.

We should recommend the reader to write the letters A, B, C, D, &c., at the corners of his maps The following diagram exhibits the whole six, separated, the manner in which they are placed in the book being shown by the heading of each, which is written at the top of the map. Those points or lines in which maps come together on the cube are denoted by the same letters, and to aid the conception of the positions of different points on the maps, when the latter are placed on the cube, a number is placed in every quarter of three of the maps, and the same number is placed in the opposite quarter of the opposite map · for example, the quarter marked 9 in the winter solstice map, is opposite to the quarter marked 9 in the summer solstice map

The hinges by which the maps are connected will enable us to see how the cube may be restored. Suppose them so small as not to



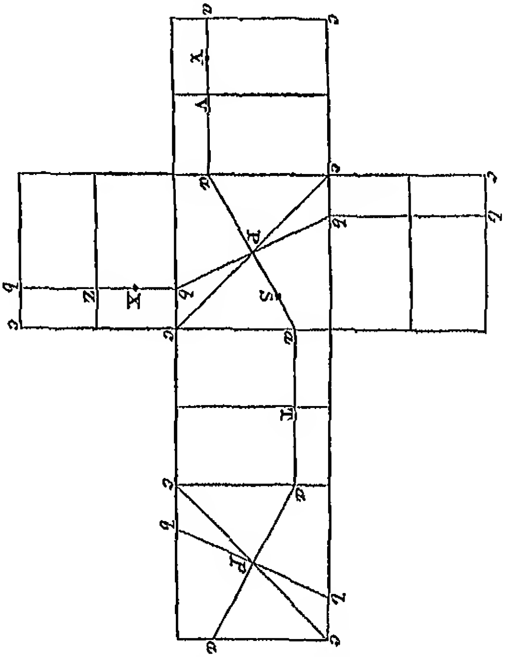
separate the edges of adjacent maps by any perceptible quantity; and let the whole system be supported at the point P. The four adjacent maps will then fall into the four sides of the cube, which will be completed by bringing up the south polar map, and fixing it to that of the vernal equinox by the clasps shown in the diagram. The points of different maps which have the same letters will now have fallen together. Thus L on the vernal equinox map, will meet

L on the winter solstice map; and the points marked *o* on the vernal equinox, winter solstice, and south polar maps, will come together.

As we cannot here pretend to give a complete doctrine of the sphere, we presume our reader to have the common knowledge of that subject, and shall endeavour, by applying all our explanations to the *maps*, and not to the *globe*, to elucidate the former by those ideas with which he is supposed to be familiar on the latter.

1. P, *p*. The north and south poles, or points about which the diurnal motion of the earth makes the heavens appear to turn. They are the only fixed points in the heavens. Any *fixed* star is always at the same distance from P. This distance, or angle contained between P and a star, is the *north polar distance* of the latter.

2. The line G H, H *g*, *g h*, *h* G. The representation of the great circle called the equator, every point of which is equally distant from the north and south poles. It is a square which divides the



cube into two *hemi-cubes*, each exactly like the other. The angular distance at which a star is from the *point nearest to it* of the equator is its *declination*, which is *north* or *south*, according as the star is in the hemi-cube which contains the north or south pole. The declination and polar distance together make up the distance between the pole and the equator, which is 90° In the diagram of page 23, the *north polar distance* of S is the angle represented by P S; its *declination*, which is north, is the sum of the angles represented by T *a* and *a* S The north polar distance of X is the sum of the angles represented by P *b* and *b* X; its declination is that represented by Z X. And Y has the south declination represented by V Y.

Declination on the globe of the heavens answers to *latitude* on the globe of the earth, or, as we must now call it for distinction, *geographical* latitude. Thus when a spectator sees a star directly over his head, he knows that the declination of that star is the same as the latitude of his own position. The reader may now find those stars which will in the course of the day pass over his head, he being in London in latitude 51½°. The polar distances of all such stars will therefore be about 38½°, and he will find among the most considerable of those which pass nearly over head, β and γ in Draco, η and γ in Ursa Minor, and α in Perseus

3 The double line L M, M *l*, *l m*, *m* L, is the representation of the *ecliptic*, or the great circle through which the sun appears to move in the course of a year. It is represented on the cube by an oblong figure or rectangle, the shorter sides of which are *m* L and M *l* Its principal points are—

Sign	At the first point of	Position of the Sun	Name
♈	Aries	In the equator, and about to pass into the northern hemisphere.	Vernal Equinox
♋	Cancer	At its greatest distance above the equator, and about to descend	Summer Solstice.
♎	Libra	In the equator, and about to pass into the southern hemisphere.	Autumnal Equinox.
♑	Capricornus	At its greatest distance below the equator, and about to ascend.	Winter Solstice.

The opposite points E, *e*, are the poles of the ecliptic, that is, the points from which the sun always keeps the same distance. The *precession of the equinoxes*, or the gradual change in the relative position of the ecliptic and equator, causes these poles to move slowly round in the direction contrary to that of the annual motion of the sun, completing a revolution in about twenty-six thousand years. The equinoctial points ♈ and ♎ therefore move backwards, that is from H towards G, and from *h* towards *g*, at the rate of about $50\frac{1}{10}''$ in a year. Properly speaking, therefore, these maps (and all others) become incorrect in time; but owing to the smallness of the precession, it will be more than a century before they are practically useless.

4. As yet we have only mentioned the distance of a star from the pole, or from the equator, as a means of fixing its position. But a star might move round the pole, without changing its distance from it, and while it did so would be said to change its *right ascension*. The *right ascension* of a star is the following. Let a great circle be drawn through the place of the star, and through both the poles P and *p*. Such a circle is called the *hour* circle of the star. In the figure of page 23, various hour circles are represented as they appear on the disjointed maps. Any one may be found by keeping the same letter in view. Each one on the cube is a rectangle, and any one may be obtained by cutting the cube by a plane which passes through the axis. Those parts of the hour circles which are found in the north or south polar maps are represented by straight lines passing through P and *p*; those parts which are found on any of the other maps are lines parallel to two of the sides of the map. The right ascension of the star is the angle made by its hour circle with that hour circle which passes through the intersections of the equator and ecliptic, which points, called the Equinoxes, are chosen as convenient stations from which to measure, in the same way as on the earth the meridian which passes through Greenwich is adopted as a convenient beginning for the measure of terrestrial longitude. This first hour circle is no other than the equinoctial colure, so that the solstitial colure, which is at right angles to the equinoctial colure, has 90° of right ascension.

It must, however, be observed, that the parts of the same hour circles which lie on different sides of the pole have right ascensions differing by 180° Thus though the part of the solstitial colure which lies on the side P ♋ has the right ascension of 90°, that which lies on the side P ♑ has the right ascension of 270°. So that the right ascension of a star depends on which half of the hour circle it is found in. The circles of right ascension are supposed to move with the stars, so as to keep their position relatively to the latter. If it were not so, a star would have every possible right ascension in the course of the twenty-four hours.

The term *right ascension* answers to *longitude* on the *terrestrial* globe, or *geographical* longitude, in the same way as *declination* to *latitude*. Thus if the star *a* is on the meridian of Berlin at the moment when the star *b* is on that of Paris, the difference of the right ascensions of *a* and *b* is the same as the difference of longitude of Berlin and Paris. It is customary to measure right ascension all round the globe, and not, as in measuring geographical longitude, to divide the globe into two halves, one east and the other west of the first meridian So that to make the globe of the heavens and earth correspond in the methods of measurement, we ought to say that 1° *west* of Greenwich is 359° of longitude, always measuring *eastward* till we come to the place the longitude of which is expressed.

The circle in the north polar diagram, which is not on the real map, is that under the points of which the zenith of Greenwich Observatory successively comes in the course of the diurnal motion. The direction of the arrows is that of the real motion of the earth, to which the apparent motion of the heavens is contrary. The hour circle, in which the zenith of Greenwich is found for the moment, is the *meridian* of Greenwich at that instant.

On a globe, it is most convenient to suppose the meridian fixed, and the hour circles to come successively under it, moving from east to west. But on these maps, the different parts of the day are most easily represented by supposing the whole cube to remain fixed, while the meridian of Greenwich successively moves over the hour circles from west to east; the first supposition representing the *apparent* motion of the stars to an observer who imagines himself fixed, while the second arises out of the real motion of the earth.

The meridian of Greenwich goes round the whole cube in twenty-four hours. In the same time it takes every possible right ascension, or moves through 360° of right ascension. This is at the rate of 15° to an hour, 15′ to a minute of time, and 15″ to a second of time. There is some confusion arising out of the use of the words *minute* and *second* in two different senses. The circle is divided into 360 degrees, each degree into 60 minutes, and each minute into 60 seconds. The latter two are called minutes and seconds of *space*—it should rather be of *angle*. The division of the day need not be repeated, its minutes and seconds are called, for distinction, minutes and seconds of *time*. The degrees, minutes, and seconds of *space*, are marked ° ′ ″; the hours, minutes, and seconds of *time*, are marked h m. s.

Thus when we say that the star α Tauri or Aldebaran, on January 1, 1830, had the right ascension $4^h\ 26^m\ 10^s$ of time, or 66° 32′ 30″ of space, we may verify the assertion as follows

4 hours	answers to 4 × 15 degrees or	60°	0′	0″
26 minutes of *time*	. . 26 × 15 minutes of *space*	6	30	0
10 seconds of *time*	. . . 10 × 15 seconds of *space*	0	2	30
$4^h\ 26^m\ 10^s$ of time	. .	66	32	30

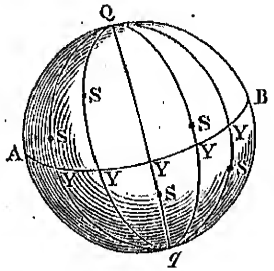
We may regard the proposition as equivalent to either of the following, in which it will immediately be recognized by the reader who has a clear notion of the term right ascension.

1. If we pass along the equator from the vernal equinox, in the direction of the sun's annual motion, we shall pass through 66° 32′ 30″ of the equator before we come under the star Aldebaran, or before we reach the point from which we might travel on a great circle through Aldebaran to the pole.

2. The angle which the hour circle of Aldebaran, or the plane of that circle, makes with the plane of the equinoctial colure, is 66° 32′ 30″.

3. The meridian passes through the vernal equinox $4^h\ 26^m\ 10^s$ before it passes through Aldebaran; or, supposing the meridian fixed, Aldebaran comes upon the meridian $4^h\ 26^m\ 10^s$ after the vernal equinox.

If instead of the equator we substitute the ecliptic, and instead of the poles (by which word, when used alone, the poles of the equator are intended) we substitute the poles of the ecliptic, then the terms *latitude* and *longitude* are used instead of *right ascension* and *declination*. They should be called *celestial* latitude and longitude, to distinguish them from *geographical* latitude and longitude, with which they have no connexion. The following general explanation will apply to these and other terms. Let A B be any great circle on the globe, and let Q and *q* be its poles. Let S be a star, and draw

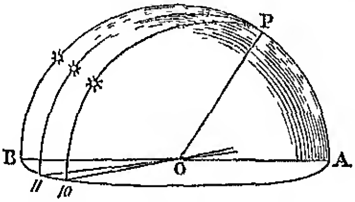


the great circle Q S *q* passing through the star, and the poles of A B, cutting A B in *y*. Then the following table connects the names given to the arcs A Y and Y S with the various names that may be given to A B.

A B	Q	*q*	A	B	A Y	Y S
Equator	North Pole	South Pole	Vernal Equinox	Autumnal Equinox	Right Ascension	Declination
Ecliptic	North Pole of do.	South Pole of do.	do. do.	do. do.	Longitude	Latitude
Horizon	Zenith	Nadir	North Point of Horizon	South Point of do.	Azimuth	Altitude

In the diagram of page 22 the dotted line which is partly in the north polar map and partly at the top of the adjacent maps encloses that portion of the heavens which is always visible at Greenwich; while the similarly dotted portion in the lower hemisphere cuts off that part which is never visible at Greenwich. The elevation of the pole above the horizon is always equal to the geographical latitude of the place of observation. Thus at Greenwich the angle made by the lines drawn from the spectator to the pole and the point of the horizon directly beneath it, or the north point, is about 51½°. Hence no star will set, unless its distance from the pole, or north polar distance, be more than 51½°. Similarly no star will rise unless its distance from the *south* pole be more than 51½°.

The name given to the projection of the sphere which we have been describing, is the *gnomonic projection* It is peculiarly adapted for the construction of sun-dials, or *gnomons*. A dial is made by erecting any opaque object, and marking out the line along which the edge of the shadow ought to fall at every hour of the day, so that, by observing the shadow, the hour of the day may be observed at the same time. The opaque object has usually a rectilinear edge, which throws a rectilinear shadow, revolving round the base of the object with the sun, and the object is usually called the *style* of the dial



If the style do not point towards the pole, there must be a different dial constructed for every different day of the year For though the sun is always on the same hour circle at any one hour of the day, noon for example, he is on different parts of that hour circle at different noons, in consequence of the motion to or from the equator, that is from or to the pole, which he has from his motion in the ecliptic Let O P be the direction of the axis of the heavens, and let the proposed dial be horizontal, the circle A B representing the spectator's horizon Then A and B being the north and south points, A P B is the spectator's meridian, in some part of which the sun must be at noon If the sun were to move up and down the arc P B, the shadow of a style drawn through O would change its direction, unless that style were in the plane of the circle B P A In this case it will always be in the direction O A, shortening or lengthening, according as the sun moves up or down, but always forming part of the line O A. Therefore, in order that noon may be always denoted by one and the same direction of the shadow, the style must be in the plane of the meridian, or noon hour circle. Similarly, in order that one o'clock P.M. may be denoted by the same direction of the shadow, the style must be somewhere in the one o'clock hour circle, and so on. Therefore the dial which serves for one day will not serve for another, unless the style be placed in some line which passes through all the hour circles. The only such line is the axis of the heavens, in the direction of which the style is therefore placed.

In the preceding figure we see the hour circles for 10 and 11 o'clock in the forenoon. The directions of the shadows of O P at those hours, on the horizontal dial, are the lines opposite to O 10 and O 11, or those lines continued backwards. The question therefore of constructing a sun-dial on a given plane, is reduced to the following. If the point where the style meets the dial be made the centre of the globe, in what points will the different hour circles cut the dial? This question is very easily solved on such maps as those we are describing, because all the great circles are represented by straight lines, and all the hour circles are readily drawn. If then, as in page 16, we draw the section in which any plane passing through the centre cuts the cube, and also lay down the points in which the representations of the hour circles cut that section, we can, by joining the centre of the sphere and cube with these points, and continuing the several lines through the centre, find the directions of the shadows *on that plane* corresponding to the various hours of the day. This would not be the best practical method, but we have mentioned it as illustrative of the name given to the projection in question.

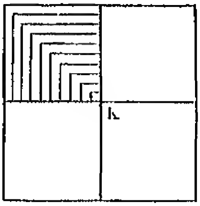
In the map of page 8, we observed the *distortion*, that is, we saw that lines which are of equal length on the globe, are not represented by equal lengths on the map. On our present maps there is some distortion, but not much, and that principally at the edges and corners. This may be seen by looking at the north and south polar maps, in which the distance between the circles of declination evidently *increases* as we proceed from the pole, these circles being separated by *equal* arcs on the sphere. But in our projection, a line drawn from the centre of the map differs from the arc which it represents by the same quantity, in whatever direction it may be drawn: that is, the distortion of lines measured from the centre, is the same in all directions. Thus in the north polar map, though *Capella*, or the star, *α* in Auriga and *Deneb*, or *α* in Cygnus, are both farther from the pole than they would be in the globe which lies in-the cube formed by the maps, yet being both very nearly on same circle of declination, they will both receive the same in- ise of their polar distance The following table will give an idea he progressive increase of the distortion as we approach the cor- of the map A globe is supposed of 10,000 inches radius, or 00 inches in diameter. The corresponding cube will, therefore, e a side of 20,000 inches A line is drawn from the centre of the p, of the number of degrees marked in the first column, on the ond is the length of the globular arc represented by that line; on third is the real length of that line on the map; while the fourth es the difference of the second and third columns, or the distortion. e nearest inch is given, and fractions of inches are rejected.

No of Degrees	Length on the Globe	Length on the Map	Difference	No of Degrees	Length on the Globe	Length on the Map	Difference
5	873	875	2	35	6109	7002	893
10	1745	1763	18	40	6981	8391	1410
15	2618	2679	61	45	7854	10000	2146
20	3491	3640	149	50	8727	11918	3191
25	4363	4663	300	55	9599	14281	4682
30	5236	5774	538	60	10472	17321	6849

Instead of supposing so large a cube, we may imagine the half le of a map to be divided into ten thousand parts, and the preced- g table will then apply to that map, the unit being, not an inch, it the twenty-thousandth part of the whole side of the map

Now if we suppose that in a crowded design, composed of objects i which the eye is not much used to dwell, (which remark is im- rtant, as what we here say would not hold of a picture of houses scenery,) the eye would not well estimate the length of any line ithin about its sixth part, the preceding distortion is immaterial itil it amounts to about the sixth part of each line that is seen. rom the above table it appears that a line drawn from the centre of ie map, representing 40°, contains 8391 parts, of which 1410 are ue to distortion. The latter is about the sixth part of the former; ence we may conclude that for 40° every way from the centre of the iap, the latter is a good representation of the corresponding part of the globe, so far as simple appearances and linear distortion measured from the centre are concerned. Indeed, in no part of the map is this distortion so considerable as to render it a bad representation of what is seen in the corresponding part of the heavens.

With regard to angular distortion, there is none in lines drawn from the centre of the map; that is, if through the centre of the map lines be drawn to two stars in it, the angle made by these lines is the same as that made by the planes of the circles which they represent. But two straight lines drawn through any other part of the map, make in some cases a smaller, in some cases a larger, angle than the circles they represent. At the corner of the map, the difference amounts to 30°; so that the circles bounding the part of a globe which falls into one of the maps in the diagram of page 19, make an angle of 120°, whereas the lines which represent them make an angle of 90°, or a right angle.



If we divide the half side of a map into ten parts, as in the preceding diagram, and describe the squares there drawn, the right angles in the corners opposite to K nearly represent the following angles on a globe, the square called the first being the smallest.

First	$90° \frac{0}{10}$	Sixth	$105° \frac{1}{10}$
Second	$92° \frac{2}{10}$	Seventh	$109° \frac{8}{10}$
Third	$94° \frac{6}{10}$	Eighth	113°
Fourth	$97° \frac{0}{10}$	Ninth	$116° \frac{6}{10}$
Fifth	$101° \frac{5}{10}$	Tenth	120°

The angular distortion is therefore a much more considerable defect than the linear distortion treated above, and must be recollected and allowed for in finding the stars in the heavens, by means of our projection. For example, looking at the north polar map, it would appear that lines drawn through the star α in Cygnus to γ in

Draco and β in Cassiopeia, are as nearly as possible at right angles. On the heavens, however, these lines will appear at an angle sensibly greater than a right angle.

We will close this chapter by a remark on the general appearance of the heavens. When we turn the eyes round, we cannot avoid the impression of being in the centre, we will not say exactly of a sphere, but of a rounded vault, compressed towards the top When, however, we look at a small part of this vault, such as can be taken in at a fixed glance, we see nothing but the appearance of a flat surface, which, by the common rules of perspective, should be represented by a part of such a map as we have been describing, *the centre of which is in the point to which the eye is most immediately directed.* The best points, therefore, on which to begin the study of the heavens from our projection, so far as tracing resemblances is concerned, are the centres of the different maps, or points near to them The following stars will be near enough to those points for the purpose.

North Polar Map .	Pole Star
Vernal Equinox	γ Pegasi
Summer Solstice .	The Belt of Orion
Autumnal Equinox . .	Spica Virginis
Winter Solstice . .	α Ophiuchi

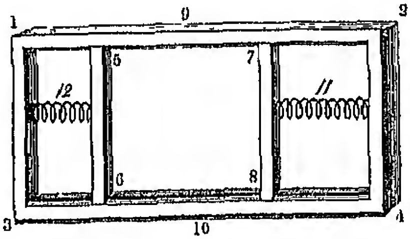
CHAPTER II.

We shall now proceed to such astronomical details as will enable the reader to adapt the map to the heavens at any hour of any day

In all that follows, we shall suppose the spectator situated at the Observatory of Greenwich, the astronomical capital of England, as well on account of the constant allusion made to that place in works on the subject, as for the convenience of reference to the Nautical Almanac, which is calculated for the meridian of Greenwich The general appearances of the heavens (telescopes and graduated instruments apart) will be the same in all parts of the United Kingdom, with this exception, that a few low stars, which rise but little above the horizon at the Land's End, will not be seen in the northern parts of the island. The utmost difference in the meridian altitudes of the same star will be about eight degrees—about as much as the distance between the two lower stars of *Charles's Wain* (β and γ of Ursa Major), and the utmost difference between the times of the same star passing the meridian of the most easterly and westerly points of the United Kingdom, will be about forty-five minutes

The diurnal motion of the earth, which is from west to east, or in the same order as the signs of the zodiac, carries the meridian of Greenwich with it The part of this meridian which is on the north and south polar maps is, as already stated, a straight line passing through the pole, and which moves round the map in the direction in which the degrees and hours are written at the edges. The parts of the meridian which lie in the ecliptic maps are straight lines perpendicular to the equator, and the daily motion of the meridian will therefore be represented on these maps by a straight line moving parallel to itself and the sides of the cube, over four faces successively, from right to left of each This will be more clearly seen in the figure of page 20, and the daily course of the zenith of Greenwich is marked by the circle in the north polar map of the figure of page 22 The difference between the method of using a common globe and our maps is this: in the globes, the *meridian* is fixed, and the *appearances* of the diurnal motion are represented by turning the globe under the meridian from *east* to *west*: in the maps, it is the *real* motion of the meridian from *west* to *east* which is supposed to take place; so that instead of talking of a star *coming upon the meridian*, we ought to speak of the meridian *arriving at a star*, or if we speak of the sun or any planet which is in motion, we should say that the meridian *overtakes the planet*

To supply something analogous to the meridian on a common globe, believing that such illustrations are always useful, we describe the following apparatus



Returning to the figure of page 20, let two pins project from the poles P and *p* (not seen) The frame 1 2 3 4 has its sides 12 and 34 a little longer than B D, but 13 and 24 equal to D *b* or A *c* The interior sides 56 and 78 are moveable in grooves cut in 12 and 34, and are repelled from 13 and 24 by the springs 11 and 12, by which they would be driven till they meet, were no resistance interposed This frame is placed upon the cube, page 20, the pins at P and *p* passing through holes at 9 and 10, so that when the frame is moved round in the direction A B C D, the force of the springs always keeps 56 and 78 close to the cube Thus 5 6 7 8 will always represent the meridian, 57 and 68 being on the north and south polar maps, and 56 and 78 on two opposite ecliptic maps

The *day* is a general term for the complete time of revolution of the meridian from any body, fixed or moveable, to the same body again. The days in common use among astronomers are the following:—

1. The *sidereal* day, or time of the earth's revolution, so that any *fixed* star which was on the meridian at the beginning of this day, is again on the meridian at the end. Instead of dating from any particular star, it is customary to begin from the time when the meridian is on the equinoctial point of Aries, or the intersection of the ecliptic

with the equator, marked ♈, and from thence to count, not two periods of 12 hours, but one only of 24 hours. Thus p. 20, when the meridian is within 15° of ♈, it is 23 hours sidereal time; when the meridian has passed the equinoctial point ♈, by 15°, it is one hour sidereal time.

2. The *real solar* day. In this case the sun is the body from which the day derives its name, the latter being the period elapsed between two successive times when the meridian overtakes the sun's centre, or two real noons. It begins when the meridian passes through the sun, and is a little longer than the sidereal day, because since the sun is also slowly moving forward at about the 365th part of the rate at which the meridian moves, the latter must not only complete the circuit of the heavens, but must also overtake the sun.

The real solar days are not precisely equal in length all the year round; for the daily motion of the sun is not the same throughout the year, being more than 61′ of longitude at the beginning of the year, when it is greatest, and less than 58′ at the beginning of June, when it is least.

3. The *mean solar* day. To avoid the inequality above alluded to, a fictitious sun has been supposed to move, not in the ecliptic, but in the equator, which setting out with the real sun, when the latter is at ♈, proceeds uniformly along the equator so as to arrive again at ♈ when the real sun is there again. The mean solar day is the interval between two successive passages of the meridian over this fictitious body, and is longer than the sidereal day for the same reason as before. The difference of the two may be easily calculated. It is found that the year (or revolution of the sun) is 365¼ mean solar days, and there must be one more sidereal revolution in that time than there are mean solar days, because in turning the sidereal into solar revolutions, there must be one whole revolution of the former broken up and wasted, so to speak, in making up the daily differences between the solar and sidereal revolution. A more familiar illustration may be found in the hands of a watch. If we call the complete rotation of the minute hand an hour, as usual, and the time between two conjunctions of the minute and hour hand by any other name, say a *period*, then twelve hours will be as long as eleven periods, and in that time, one hour will, altogether,

be employed by the minute hand in making up the differences between hours and periods. Consequently, a period exceeds an hour by the eleventh part of an hour. Apply the same principle, and divide a mean solar day, or 24 hours, *i. e.* 1440 minutes, by 365¼, we have a little less than 4 mean solar minutes for the excess of the mean solar above the sidereal day. More correctly—

Mean solar day = $24^h\ 3^m\ 56^s,6$ sidereal time

Sidereal day = $23^h\ 56^m\ 4^s,1$ mean solar time.

The distinction of day and night is unknown in astronomical reckoning. The mean solar day begins when the meridian overtakes the fictitious sun in the equator, which moment is $0^h\ 0^m\ 0$ mean solar time. The civil and astronomical reckonings then agree till midnight, which is 12^h in both, but one o'clock the succeeding morning (civil reckoning), is 13^h mean solar time (astronomical reckoning), eight in the morning is 20^h, astronomical reckoning. Consequently, six o'clock on Sunday morning, is 18^h of the day which commenced on Saturday at noon. The following examples will illustrate this:—

Civil Reckoning	Astronomical Reckoning
May 1, noon	May 1, $0^h\ 0^m\ 0^s$
Sept. 17, 6 A.M.	Sept. 16, $18^h\ 0^m\ 0^s$
Jan. 1, 11 A.M.	Dec 31, $23^h\ 0^m\ 0^s$
Aug. 12, 9 P.M.	Aug 12, $9^h\ 0^m\ 0^s$

The cause of the difference between the mean and real solar day is two-fold: first, the real sun moves irregularly, which the fictitious sun is not supposed to do, secondly, the real sun moves in the *ecliptic*, and the fictitious sun in the *equator*. Even if the real sun moved *uniformly* in the ecliptic, the meridian would not be on the real and fictitious sun at the same time, as will be evident on looking, for example, at the vernal equinox map. Suppose the real and fictitious suns each to have moved through 30°, in which case the former will be at ♉ on the ecliptic, and the latter at 30° on the equator; but the meridian must move through more than two degrees from the latter before it overtakes (or falls under) the former. The equation of time is the quantity of mean solar time in which the meridian moves from the real to the fictitious, or from the fictitious to the real sun, according to which is the foremost. It is given for every day at noon in the Nautical Almanac. It may, however, be observed, that the difference between the two is rarely so great as to be of importance in questions for which these maps may be made useful.

We proceed now to the actual employment of the maps.

The following table will show at a glance in what map to look for any point whose right ascension and declination are given.

Opposite to each map is the whole range of right ascension contained in it, the numerals signifying degrees, the Roman figures hours, and underneath, in a line marked 'Limit of Declination,' is the greatest declination which must be looked for in the hour circles where right ascensions are above. All points having higher declinations, must be sought in the north or south polar maps, according as the declination is north or south. For instance, in what map is the star whose right ascension is $16^h\ 56^m$, and declination 44° 19′ south? Recollect that 20 *minutes* of right ascension is 5 *degrees*. We find 16^h in the winter solstice map, and under 17^h (the nearest to $16^h\ 56^m$) we find 44° 0′, as the limit of declination. We must, therefore, look for the star in the south polar map. If the declination be upwards of 45°, north or south, the star is certainly in the corresponding polar map.

The method of laying down a star or planet, when its right ascension and declination are known, hardly needs explanation. If the declination be so great, that the star must be in one of the polar maps, look for the right ascension on the edge of the map, and having found it, proceed along the straight line drawn from the part of the edge just found, until you come to the circle of declination of the star, which may be found by looking at the diagonals of the square, on which the declinations are marked. If the star be on one of the ecliptic maps, the right ascension must be looked for on the equator, or on the upper or lower edge, and the declination on either side.

The positions of the sun, moon, and planets, for every day in the year, may be found in the "Nautical Almanac," which work will be necessary to all who make much use of the maps. Of the sun, the longitude only need be found, which must be looked for on the ecliptic. The places of the planets may be taken from the same work, either as seen from the earth, or from the sun. For the first, the *geocentric* right ascensions and declinations must be taken; for the second,

Vernal Equinox Map.	315 XXI.	320	325	330 XXII	335	340	345 XXIII.	350	355	0 O	5	10	15 I	20	25	30 II.	35	40	45 III.
Summer Solstice Map.	45 III.	50	55	60 IV.	65	70	75 V.	80	85	90 VI.	95	100	105 VII.	110	115	120 VIII.	125	130	135 IX.
Autumnal Equinox Map.	135 IX.	140	145	150 X.	155	160	165 XI.	170	175	180 XII	185	190	195 XIII	200	205	210 XIV	215	220	225 XV.
Winter Solstice Map.	225 XV.	230	235	240 XVI.	245	250	255 XVII	260	265	270 XVIII	275	280	285 XIX.	290	295	300 XX	305	310	315 XXI.
Limit of Declination.	35° 16′	37° 27′	39° 19′	40° 54′	42° 11′	43° 13′	44° 0′	44° 34′	44° 54′	45° 0′	44° 54′	44° 34′	44° 0′	43° 13′	42° 11′	40° 54′	39° 19′	37° 27′	35° 16′

the *heliocentric*. The orbit of any planet may be found with sufficient nearness by laying down two positions of the planet in the same map, and drawing a line through the two. This may be continued on the other maps by the methods explained in p. 15 and 16.

The time at which any part of the heavens comes on the meridian at Greenwich, may be found from the same work by means of the column headed "mean time of transit of the first point of Aries" (page 22 of each month). To the time at which the equinox passes the meridian, as thus found, add the right ascension of a star in time, and the result will be (correctly enough) the time of transit of that star But if the sum exceed twenty-four hours, subtract twenty-four hours, and the remainder is the time of transit. The day begins from noon, as explained in page 37.

For ascertaining phenomena with a less degree of precision, but sufficient for the purposes of amusement or elementary instruction, the following table will be sufficient, in which the sun's longitude at noon is given for every ten days within a quarter of a degree, and the right ascension within a minute

Longitude and Right Ascension of the Sun at Noon.

		Deg	Qu	Hrs	Mns			Deg	Qu	Hrs	Mns
Jan.	1	280	3	18	46	July	10	107	3	7	17
	11	290	3	19	30		20	117	1	7	57
	21	301	0	20	13		30	126	3	8	37
	31	311	1	20	55	Aug.	9	136	1	9	15
Feb.	10	321	1	21	35		19	146	0	9	53
	20	331	2	22	14		29	155	2	10	30
March	2	341	2	22	52	Sept	8	165	1	11	6
	12	351	2	23	29		18	175	0	11	42
	22	1	2	0	5		28	184	3	12	18
April	1	11	1	0	41	Oct	8	194	3	12	54
	11	21	0	1	18		18	204	3	13	31
	21	31	0	1	55		28	214	2	14	9
May	1	40	2	2	33	Nov.	7	224	3	14	49
	11	50	1	3	11		17	234	3	15	29
	21	60	0	3	51		27	244	3	16	11
	31	69	2	4	31	Dec.	7	255	0	16	55
June	10	79	0	5	12		17	265	1	17	39
	20	88	2	5	54		27	275	1	18	23
	30	98	1	6	35						

The degrees of longitude are laid down on the ecliptic, and thus we may find the position of the meridian at noon, and, what is of more importance for our present purpose, at midnight, for half a degree added to the sun's longitude at noon, will give the longitude at midnight sufficiently near, and 180° added to the longitude, or subtracted from it if it be greater than 180°, will give the longitude of that point of the ecliptic which is opposite to the sun at midnight, or which is then visible. Having found this point, take notice what conspicuous stars are on, or nearly on, the meridian.

The degrees on the ecliptic are counted by *thirties*, each 30° being a sign of the zodiac. The following table shows the degree of longitude at the beginning of each sign, and the symbol by which it is denoted. The *astronomical* sign must not be confounded with the *constellation*, for a reason which we shall afterwards see.

Astronomical name of the sign	Symbol	Degree of Longitude at the commencement of the sign	Map in which the commencement of the sign is to be found
Aries	♈	0	Vernal Equinox
Taurus	♉	30	" "
Gemini	♊	60	Summer Solstice
Cancer	♋	90	" "
Leo	♌	120	" "
Virgo	♍	150	Autumnal Equinox
Libra	♎	180	" "
Scorpio	♏	210	" "
Sagittarius	♐	240	Winter Solstice
Capricornus	♑	270	" "
Aquarius	♒	300	" "
Pisces	♓	330	Vernal Equinox

For example, required the state of the heavens at midnight, on the 1st of January. The sun's longitude is half a degree more than $280\frac{3}{4}°$, or $281\frac{1}{4}°$. Subtracting 180° from this, we have $101\frac{1}{4}°$, the longitude of the point of the ecliptic, which is on the visible part of the meridian at midnight. This point is $11\frac{1}{4}°$ past the first point of Cancer, marked ♋ in the summer solstice map. Finding this point, we see that the visible part of the meridian towards the south, has at midnight, January 1st, a little more than 102° of right ascension, or in the more common phraseology, the hour-circle of 102 is nearly on the meridian. The constellations Canis Major and Gemini are on it, and the bright star of the former, Sirius, has been passed by the meridian, or has appeared to cross the meridian about ten minutes before midnight. Orion is to the westward, the belt having passed the meridian at about a quarter to eleven o'clock. Pollux, one of the principal stars in Gemini, will be overtaken by the meridian, or will appear to cross it, in about 50 minutes. Looking to the north polar map, in which the continuation of the meridian is a line nearly close to the radius drawn from 102° to the pole, we find Lynx and Camelopardus on the meridian, but no remarkable star The Great Bear is in the east, and Cassiopeia in the west Very low down, between the north and north-west, is the bright star in Cygnus, while low in the north are the stars in the head of the Dragon If we want the position of the heavens at eight o'clock the same evening, or four hours before midnight, we must put the meridian back four times 15°, or 60°, which gives it a little more than 42° of right ascension Place the vernal equinox and summer solstice maps side by side, the former on the right, and look at the hour-circle of 42° We see the bright star Menkar, in the whale, just coming on the meridian, the head of Aries passes about fifty minutes before eight, and the Pleiades will pass about nine, P M.

Looking at the north polar map, we find Algol in the head of Medusa just past the meridian, where Capella will be in two hours, and Andromeda was two hours ago The Great Bear has passed the meridian *below*, or on the *north* side of, the pole, about three hours

The visible part of the meridian is determined in the northern hemisphere as follows. Measure from the pole, on the north side, the latitude of the place, which gives the northern point of the horizon, measure from the equator towards the south, the angle by which the latitude of the place falls short of 90°, which gives the south point of the horizon.

Resuming the first of the preceding examples, the latitude of Greenwich being 51½°, we find the bright star α in Lyra, very nearly at the north point of the horizon at midnight, January 1. At or near the south point of the horizon, there is no remarkable star, but α in Canis Minor is about 10° above it.

The whole heavens may be divided into three portions, with regard to any place of observation: 1, a portion which is never below the horizon; 2, a portion which never rises above the horizon; 3, a portion which rises and sets.

Since the pole is always elevated above the horizon by an arc equal to the latitude of the place, a small circle drawn round the pole, and distant from it at every point, by the latitude of the place, will contain the *circumpolar* polar of the heavens, as it is called, which is visible throughout the whole of the twenty-four hours. All stars contained in this are called *circumpolar* stars. Similarly, since the other pole (that is in our hemisphere, the south pole) is depressed below the horizon by an arc, equal to the latitude of the place, a circle equal to the former drawn round the south pole contains a part of the heavens which never rises, equal in magnitude to that which never sets. The rule, in the northern hemisphere, for determining whether a star falls in either of these portions, is;—if the declination of the star be greater than the *complement** of the latitude of the place, (for Greenwich this is 38° 31′, the latitude being 51° 29′,) it never sets if the declination be north, or never rises if the declination be south.

The remaining part of the sphere, containing every point which has *less* declination (north or south) than the complement of the latitude of the place, rises and sets alternately.

Looking at our maps, we find that the circumpolar portion at Greenwich includes the whole of the north polar map, with the exception of very small segments at the corners, containing no large star. It also includes four small portions of the ecliptic maps, as previously described in page 28. Also, the portion which never rises at Greenwich contains the whole of the south polar map, the corners only excepted, and four similar southern portions of the ecliptic maps.

Our maps (and indeed all others) are very ill suited to determine the actual time of rising or setting of any star. The best instrument for this purpose, is a planisphere hereafter to be noticed, while

* The *complement* is what remains after subtracting an arc from 90°. Thus 30° is the complement of 60°.

the correct method of ascertaining any such point must be left for those who are acquainted with spherical trigonometry We give here a rough table of the times at which some of the most remarkable stars, visible at Greenwich, come upon the meridian of that place, for the first day of every month. Where the star is circumpolar, the meridian passage chosen is that south of the pole. A few stars of inferior magnitudes are added in the case where a remarkable constellation has no star of the first magnitude.

Letter and Constellation	Name	Jan	Feb	March	April	May	June	July	August
γ Cassiopeæ		5¾	3¾	2	*11¾	* 9¾	* 7¾	* 5¾	* 3¾
α Arietis		7¼	5¼	3½	1¼	*11¼	* 9¼	* 7¼	* 5¼
α Ceti	*Menkar*	8¼	6¼	4½	2¼	12¼	*10¼	* 8¼	* 6¼
α Persei		8½	6½	4¾	2½	12½	*10½	* 8½	* 6½
α Tauri	Aldebaran	9¾	7¾	5¾	3¾	1¾	*11¾	* 9¾	* 7¾
α Aurigæ	Capella	10¼	8¼	6½	4½	2½	12½	*10½	* 8½
α Orionis	*Betelgeux*	11	9	7¼	5	3	1	*11	* 9
α Canis Maj.	Sirius	*12	10	8	6	4	2	12	*10
α Canis Min	Procyon	*12¾	10¾	8¾	6¾	4¾	2¾	12¾	*10¾
β Geminorum	Pollux	*12¾	10¾	9	7	5	3	1	*11
α Hydræ	Cor Hydræ	* 2½	*12½	10¾	8¾	6¾	4¾	2¾	12¾
α Leonis	Regulus	* 3¼	* 1¼	11½	9¼	7¼	5¼	3¼	1¼
α Ursæ Maj.	*Dubhe*	* 4¼	* 2¼	*12¼	10¼	8¼	6¼	4¼	2¼
α Virginis	Spica Virginis	* 6½	* 4½	* 2¾	*12½	10½	8½	6½	4½
α Bootis	Arcturus	* 7½	* 5½	* 3½	* 1½	11½	9½	7½	5½
α Serpentis		* 8¾	* 6¾	* 5	* 3	* 1	11	9	7
α Scorpii	Antares	* 9½	* 7½	* 5¾	* 3¾	* 1¾	11¾	9¾	7¾
α Ophiuchi	*Ras Alhagus*	*10¾	* 8¾	* 6¾	* 1¾	* 2¾	*12¾	10¾	8¾
γ Draconis		*11¼	* 9¼	* 7¼	* 5¼	* 3¼	* 1¼	11¼	9¼
α Lyræ	*Vega*	*11¾	* 9¾	* 8	* 5¾	* 3¾	* 1¾	11¾	9¾
α Aquilæ	Atair	1	*11	* 9¼	* 7	* 5	* 3	* 1	11
α Cygni	*Deneb*	1¾	*11¾	*10	* 8	* 6	* 4	* 2	*12
α Cephei	*Alderamin*	2½	12½	*10¾	* 8½	* 6½	* 4½	* 2½	*12½
α Aquarii		3¼	1¼	*11¼	* 9¼	* 7¼	* 5¼	* 3¼	* 1¼
α Piscis Aust.	Fomalhaut	4	2	12¼	*10¼	* 8¼	* 6¼	* 4¼	* 2¼
α Pegasi	Markab	4¼	2¼	12¼	*10¼	* 8¼	* 6¼	* 4½	* 2¼
α Andromedæ	*Alpheratz*	5¼	3¼	1½	*11¼	* 9¼	* 7¼	* 5¼	* 3¼

Letter and Constellation	Name	Sept	Oct	Nov	Dec	Time between rising and coming to the meridian	Point of the heavens in which it rises
α Cassiopeiæ		* 1¾	11¾	9¾	7¾	—	—
α Arietis		* 3¼	* 1¼	11¼	9¼	8¼	N E b.E
α Ceti	*Menkar*	* 4¼	* 2¼	*12¼	10¼	6¼	E.
α Persei		* 4½	* 2½	*12½	10½	—	—
α Tauri	Aldebaran	* 5¾	* 3¾	* 1¾	11¾	7¼	E.N E
α Aurigæ	Capella	* 6¼	* 4½	* 2¼	*12¼	—	—
α Orionis	*Betelgeux*	* 7	* 5	* 3	* 1	6½	E b N
α Canis Maj	Sirius	* 8	* 6	* 4	* 2	4¾	E S E.
α Canis Min	Procyon	* 8¾	* 6¾	* 4¾	* 2¾	6¼	E b N
β Geminorum	Pollux	* 8¾	* 7	* 1¾	* 3	9	N E b N.
α Hydræ	Cor Hydræ	*10½	* 8¾	* 6½	* 4¾	5¼	E b.S
α Leonis	Regulus	*11¼	* 9¼	* 7¼	* 5¼	7¼	E.N E.
α Ursæ Maj	*Dubhe*	12¼	*10¼	* 8¼	* 6¼	—	—
α Virginis	Spica Virginis	2½	12½	*10½	* 8½	5¼	E b S
α Bootis	Arcturus	3½	1½	*11½	* 9½	7¾	N E b E.
α Serpentis		4¾	3	12¾	*11	6½	E b N.
α Scorpii	Antares	5½	3¾	1½	*11¾	3½	S E
α Ophiuchi	*Ras Alhague*	6¾	4¾	2¾	12¾	7¼	E.N E.
γ Draconis		7¼	5¼	3¼	1¼	—	—
α Lyræ	*Vega*	7¾	5¼	3¾	1¾	—	—
α Aquilæ	Atair	9	7	5	3	6¾	E b N.
α Cygni	*Deneb*	9¾	8	5¾	4	—	—
α Cephei	*Alderamin*	10½	8½	6½	4½	—	—
α Aquarii		11¼	9¼	7¼	5¼	6	E
α Piscis Aust.	Fomalhaut	*12	10¼	8	6¼	2½	S E b S.
α Pegasi	Markab	*12¼	10¼	8¼	6¼	7½	E N.E
α Andromedæ	*Alpheratz*	* 1¼	11¼	9¼	7¼	8¾	N E

The first column contains the usual method of naming the star, by its constellation and letter. The second contains the peculiar name of the star, where it has one; but when the name is seldom if ever used, it is put in italics: thus α Lyræ is hardly ever called Vega, while α Canis Majoris is usually called Sirius. The succeeding twelve columns show, within about a quarter of an hour, the times when the various stars will be on the meridian of Greenwich on the first day of the various months of the year. The asterisk denotes *midnight* or *after midnight*, the figure without asterisks *noon* or *afternoon* Thus (*12) is midnight, and (12) is noon; (*2¾) is a quarter to three in the morning, (2¾) the same in the afternoon; (*10) is ten in the morning, (10) ten in the evening. The last column but one shows the interval of time between the star's rising and coming on the meridian, or between the latter and its setting; and the last column shows near which point of the compass it rises; while the substitution of W. for E. throughout will show the same for the setting Where the last two columns are vacant, the star is circumpolar, that is, not sufficiently distant from the pole to rise or set

For instance, we wish to know the position of the constellation Orion on the 1st of March Opposite to α Orionis, and under March, we find (7¼), or this star comes on the meridian at about a quarter past seven in the evening. In the last column but one, we see 6½, or the star has risen six hours and a half before it comes on the meridian, and will set six hours and a half after coming to the meridian. That is, it rose at about a quarter to one, P.M., and will set at about a quarter to two, A.M. It rises east by north, and sets west by north *

To correct the preceding table for the intermediate days, abate a quarter of an hour for every four days from the first of the month. Thus on the 18th of December, seventeen days from the first, the stars will be on the meridian about an hour earlier than the time marked in the table for the first. Thus the learner may judge in what part of the heavens to look for any remarkable constellation at any time of the year; and may find the smaller stars by more particular comparison of the map with the portion of the heavens so found

The most useful problem for which our maps offer no great facilities, is the finding of the distance between two stars But when

* Very few persons (except seamen) have distinct ideas upon the meaning of the more complicated points of the compass. The following two rules embrace all the cases. When the letters indicating two points are joined together, the point which is half way between the two is meant: thus N E is half way between north and east; and N N.E. is half way between north and north-east When the letters of two points are joined together with the intermediate word *by*, or the letter *b*, it means the point which comes next after the first, in going towards the second thus, N.*b*.E. is the point which follows north towards the east; S E.*b*.S. is the next point to south east, looking towards the south

the right ascensions and declinations of the stars are known, a simple geometrical construction will overcome the difficulty, which we insert more readily, as the same may also be applied to the finding of the distance between two given places on the earth's surface

Of the two methods which we now give, the first is the construction of a problem in spherical trigonometry, is independent of the map, and is meant to be applied when the stars the distance of which is to be measured, lie upon different maps. It is taken from Sir Jonas Moore's system of mathematics, and requires only a scale or table of chords. The second method is conveniently applied when the stars are upon the same map, and requires only a scale of equal parts

To find the distance between two stars, proceed as follows —

1. Find the right ascensions and declinations of the stars

Case First	Case Second.
1st star R. A. 358° Dec 57½° N.	1st star R. A 94½° Dec 16° N
2d star R. A. 307½° Dec. 44¼° N.	2d star R A 344° Dec 30½° S,

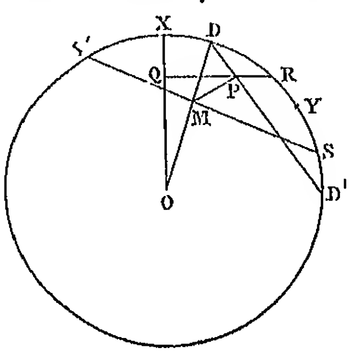
2 Take the difference of the right ascensions; or if this difference be greater than 180°, subtract it from 360°, and take the remainder. Call this A.

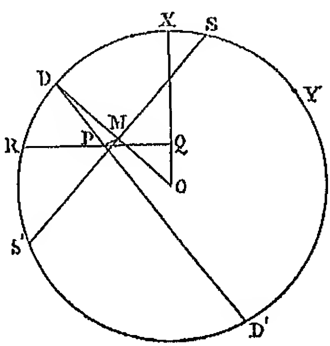
Case First	Case Second
A = 50½°	A = 110½°

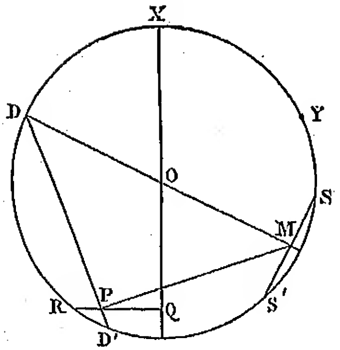
3. If the declinations be both north, or both south, subtract both from 90°; if one be north and the other south, add either to 90° and subtract the other from 90°. Call the results B and C.

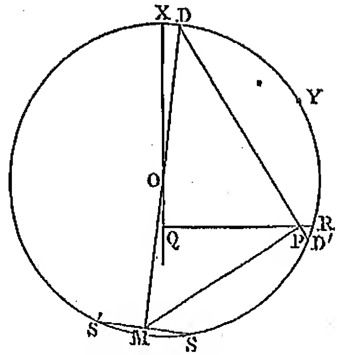
Case First	Case Second
B = 32½°	B = 106°
C = 45¾	C = 59½

4. Take a circle whose radius is the chord of 60°, and from the centre O draw any radius O X









5. Set off X Y with the chord either of B or C, and Y D, Y D′ with the chord of the other.

6. Set off D S, D S′, with the chord of A.

7. Draw O D, D D′, S S′.

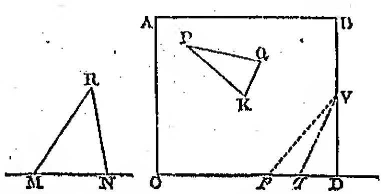
8. From M the intersection of O D and S S′, draw M P perpendicular upon D D′: from P draw P Q perpendicular upon O X or O X produced, and produce P Q to meet the circle in R.

9. Measure X R with the compasses, and find the angle of which it is the chord; that angle is the distance of the stars required.

The answer in the first case is $33\frac{1}{2}°$, and in the second $115\frac{3}{4}°$.

To apply this to finding the distance between two places on the earth, use longitudes instead of right ascensions, latitudes instead of declinations, but take the *difference* of longitudes for A, only when both are east or both west, and their *sum* when one is east and the other west. In all other respects, the rules are precisely the same. When the angular distance is found, allow 70 miles to a degree, and subtract from the result, its hundreth part, which will be sufficiently exact.

The second method of finding the angular distance of two stars is as follows:—



Let P and Q be the stars, K the centre of the map, and D V a half-side. Set off D p, D q, respectively equal to K P and K Q, and draw V p, V q. On P Q, or on a line M N, equal to P Q, construct a triangle, of which the remaining sides R M, R N, are respectively equal to V p, V q Then the angle at R is the angular distance of the stars P and Q on the globe

If the side of the map be considered too large a scale, any convenient length may be taken to represent an inch, and a scale of equal parts may be used

CHAPTER III

We now proceed to some historical and critical account of the gnomonic projection.

It has been usual to distinguish maps of the stars from those of the earth, by the name of *planispheres*, or representations of the sphere upon a plane This name is rejected because both species equally merit the latter title. The first planispheres of which we have any distinct account are those of Ptolemy, or rather of Hipparchus and Ptolemy It appears that the former knew the *stereographic projection*, in which the eye is placed at a point of the sphere, and the plane of projection is perpendicular to the diameter which passes through the eye. Hipparchus is said, by constructing such a projection, and laying down sixteen principal stars, to have provided an instrument for determining the hour of the night. But Ptolemy is the first writer on the stereographic projection, whose work has come down to us, not indeed in Greek, but only by an Arabic version, which latter was rendered into Latin by Commandine.

The distinguishing properties of the stereographic projection are, 1. that every circle of the sphere, great and small, is represented by a circle, 2 that the angle made by the projections of two circles which intersect, is the same as that made by the circles themselves. But neither appear to have been known either to Hipparchus or Ptolemy, except the first property in the case of *great* circles, which is the more curious, as in the conic sections of Apollonius, published long before the time of the latter, a proposition is given which very nearly amounts to the same thing as the first-mentioned property. The first who distinctly announced it for *every* circle was Jordanus, in a treatise on the planisphere, written at the beginning of the thirteenth century, but not published till 1507. The oldest known demonstration of the second property is in Leadbetter's Astronomy, London, 1728.

For the projection of a whole hemisphere, the stereographic has some considerable advantages, but not so for smaller portions of the sphere At and near the point opposite to the eye it is nearly the same as the gnomonic projection, but farther from the centre of the map the distortion becomes considerable. For common use in the finding of stars, it is altogether inadmissible, since stars which lie on the same line, or nearly so, in the apparent heavens, are placed in a circle in the stereographic map, to which circle the eye has no guide. For example, it is seen in our summer solstice map, that Procyon, Rigel, and γ Eridani are nearly in a line with each other, as are also α Columbæ, Sirius, and Procyon. Neither of these would be suspected, on looking at a stereographic projection

There is, however, one very useful application of the stereographic projection, (as of all others which suppose the eye to be in the axis, and the plane of projection parallel to the equator,) which we notice because it is most effective in the point where our maps are weakest; namely, in laying down the various positions of the horizon. If a common globe be rectified for the latitude of any place, it is then indifferent whether we suppose the globe fastened to the axis, and turning with it, while the horizon remains fixed, or whether we suppose the horizon to be attached to the axis, which turns it the contrary way, while the globe remains fixed. If we lay this down on a stereographic projection, of which the place of the eye is the south pole of the axis, the horizon will continue throughout its whole motion to be represented by the same circle, moving in the plane of the equator, round a point, the position of which depends upon the latitude of the place, being nearer the circumference the less is the latitude. This was applied by Apian,* in his *Cosmographia*, to a planisphere for geographical purposes, and by the late Dr Wollaston† to a similar one for the heavens. By it can be found immediately the stars visible at the place for any hour of any day in the year, together with the position on the visible hemisphere occupied by each, as also the time of rising,

* For a short account of whom, see *Penny Cyclopædia*

† Possibly the *Usus Astronomicus*, &c, of Bartschius, published in 1661, may have previously contained the same thing See Lalande, *Bibliographie Astronomique*, page 249 The same may be said of the planisphere of Stampioen, which had a moveable horizon. See page 311.

setting, and coming on the meridian of each, to within about five minutes*

The remaining projection which was known to Ptolemy, is that now known by the name of orthographic, called by him the Analemma, and described in his work of that name, which has descended to us in a Latin translation Its principle is not reducible to that of a picture, unless we suppose the eye placed at an infinite distance. It may be more easily conceived as follows. Let the hemisphere to be projected be placed with its circular base horizontal, the place of each star is the point of the ground-plane which is directly under the star The distortion of this projection is very considerable towards the edges, and all circles are represented by ellipses, except those which are parallel to the plane of projection. It has however, like all other projections, its own peculiar advantages; one of which is, that, supposing the plane of projection to be the equator, a star is very easily laid down, when its right ascension and declination are given.

Delambre† attributes to Ptolemy a knowledge of the gnomonic projection, which he appears to us to infer from very slight premises. We do not know that he laid down any map of the heavens which supposed the eye to be at the centre of the sphere

The first modern work on the sphere which enjoyed any considerable reputation, was that of John de Sacro Bosco, or Sacro Busto, an Englishman, probably, from his name, either called Holywood or Halifax, or else born at one of those places He studied, first at Oxford, afterwards at Paris, and died in 1256, leaving behind him a Latin treatise on the sphere, which for more than three hundred years continued to be the principal one in use. Being written in Latin, it was as well known on the continent as in England, and probably much better, for among the many commentators on the aforesaid work, there is not the name of any Englishman of note.

The first work which we can find, professing to treat of the sphere, and written in English, is the "Castle of Knowledge," by

* By much the best planisphere of this kind which we have found, is that constructed by Messrs Smith and Son, 172, Strand. It is, of course, adapted to Greenwich, but will not be very wrong, and may be easily corrected, for any part of England.

† Hist Ast. Anc. vol. ii. p. 486.

Robert Recorde, physician, best known as the first introducer of algebra into this country. It was published in 1556, and dedicated in English to Queen Mary, and in Latin to Cardinal Pole. It is an unfavourable specimen both of typography, uniformity of spelling, and accuracy of reasoning, but contains much curious information on the then existing notions of astronomy.* It does not refer to any English work on the subject, but only to Sacro Bosco and foreign commentators. It does not contain any distinct account of either projection, but the orthographic projection is employed in the figures.

In 1590, Thomas Hood published "The Use of the Celestial Globe in Plano, set forth in two Hemispheres," the first work in English, which appears in the *Bibliographie Astronomique* of Lalande, and of which he remarks, "L'Astronomie commencait à percer en Angleterre." This work consisted of a very meagre account of the stereographic projection, together with an explanation of the mythological constellations, embellished with some surmises † of the author.

The first work on the *gnomonic* projection appeared at Rome in 1612, with the following title:—

"Prospectiva nova Cœlestis, seu Tabulæ peculiares ad Asterismos in Plano delineandos, auctore R. P. Christophoro Grienberger, Soc. Jesu."

The author was born, according to Lalande, in 1561, at Halle in the Tyrol, and died at Rome, in 1636. Another edition appeared in 1679, edited by H. A. Langenmantel, a Benedictine canon, which is in the British Museum. It consists principally of tables for laying down the various constellations in this projection.

In 1674, folio maps, similar to those of which this work treats, appeared at Paris, under the following title:—

* It is stated in this work, but no where else that we have found, that the milky way was anciently called "Watling Street," and the seven stars of Ursa Major, "the brood hen."

† We quote the following, as part of one of our old "Explanations of Maps of the Stars."

"*Scholar.* I marvell why, seeing she (Ursa Major) hath the forme of a beare, her taile should be so long.

"*Master.* Imagine that Jupiter, fearing to come too nigh unto her teeth, layde holde on her tayle, and thereby drewe her up into the heaven, so that shee of her selfe being very weightie, and the distance from the earth to the heavens very great, there was great likelihood that her taile must stretch. Other reason know I none."

"Globi Cœlestis in Tabulas Planas reducti Descriptio, auctore P Ignatio Gastone PARDIES, Soc. Jesu Mathematico, opus posthumum."

These were six maps, representing the six sides of a cube circumscribed about the sphere, as described in the first Chapter of this treatise.

There were one or two other editions The first is in the British Museum, and presents six maps corresponding to those on which this work treats, and in particular we must notice that the figures of the constellations are turned with their backs towards the spectator, in the manner represented in our plates, though the maps represent the interior of the globe. On this point we shall presently speak

In the course of mathematics projected by Sir Jonas Moore, for the Mathematical School at Christ's Hospital, and published after his death in 1681, he has placed, at the end of the Cosmography, six maps reduced from those of Father Pardies, but in other respects a perfect copy of them These are, as far as we know, the only maps of the kind yet published in England. Another projection of the same species, but which does not appear to have been copied, is to be found in the Atlas of Doppelmaier, published at Nuremburg, in 1742 The constellations are arranged in the same manner with regard to fronts and backs.

We now come to the reasons which have recommended the adoption of the gnomonic projection, in preference to any other. Generally speaking, the practical astronomer has no need of maps, since catalogues have entirely superseded both these and globes In such catalogues the stars are arranged in the order of their right ascensions, which are given, as also their declinations. The degree of accuracy required is such, that unless maps were at least five hundred times as long and as broad as ours, and made of some material which does not shrink, they could not supersede a catalogue; and even then, there would be many inconveniences independent of their size. The only case in which a map might be useful is where some new object, such as a comet, having been observed for several days, and then lost, a rough approximation to its track is wanted, which may tell the observer in what direction to look for it again. But for this purpose, a map containing a sixth part of the heavens could never be wanted, and the Atlases of Flamsteed or Bode, which are well known to astronomers, and in which single constellations are laid down on a large scale, would better serve the purpose. Consequently, the astronomer has no use for our maps, other than that which is common to him with the rest of the world.

The common reader is desirous of seeing the relative position o the constellations, and seldom or never wants any large development of a single portion of the heavens. Therefore maps of individual constellations would only perplex him by their minuteness, as well as by their detached character. At the same time, the possessor of a moderately good telescope, who pursues star-gazing as an amusement, requires more exact detail than could be furnished in a very small space To the first description of persons, every projection is practically useless, which does not preserve the main character of the relative positions, that is, which does not place those stars in the same line, which appear in the same line in the heavens. All purposes are better served in the gnomonic projection upon the circumscribed cube, than in any other with which we are acquainted, for as each map contains a sixth part of the whole celestial sphere, the most important groups are to be found in the same map, and as the straight line, which joins two stars on the same map, is the representative of the apparent shortest distance between them, all the stars which appear on the same line in the heavens are found on the same line in the map. This is the particular advantage of the method of projection, and by it, a person who has no idea of arithmetic or geometry, or even of astronomy, except knowing the names of the principal stars, might possibly substantiate his claim to be the discoverer of a new comet; or, if he were very lucky, of an old one whose return is expected.

Suppose that a person, so circumstanced, were to see, in an evening's walk, some faint and cometary-looking appearance in a particular portion of the sky, near the constellation Orion. Upon looking at neighbouring stars, he sees that it appears exactly in a line with the two shoulder stars of Orion (α and γ), and also with the star in the foot (β), and the star above, and nearest to it in a line parallel with the belt, which is in Eridanus, and is marked β, Having made these *observations*, he has, on his return home, the power of obtaining the approximate place of the body, with a facility, and we may almost say, with a correctness, which Ptolemy might have envied. On drawing straight lines through the stars above named, in the summer solstice map, it will be seen that the right ascension of the appearance observed must have been 69°, and its declination above $4\frac{1}{2}$° North.

The same method will of course apply to finding out the appellation of any particular star, which is not known, by means of two which are known. Draw a line in the winter solstice map through α Aquilæ, and α Lyræ, and it will then become very easy to detect α and β Capricorni, θ, β, γ, ζ, and ϵ Aquilæ, the three stars in Sagitta, β Cygni, and γ Lyræ

It will be better for the beginner to observe, for himself, stars which appear in one line, and to proceed to compare them with the map, than to follow the directions laid down in any book.

The relative position of the constellations is not easily recollected; their forms, and the manner in which they are dispersed on the globe, are too irregular. To fix in the mind the first rough idea of their position, perhaps the best way would be to refer them to corresponding portions of the terrestrial globe, in the following manner; or at least, it may be worth while for the reader to try whether he can derive any advantage from such a comparison. Let the instant chosen be the commencement of the sidereal day at Greenwich, that is, let the vernal equinox be on the visible part of the meridian at that place. Then the following constellations will be vertical to, or over the heads of, the countries which are marked opposite to them. We have chosen as often as possible the central part of the constellation, or boundaries where they were more convenient; and it must be recollected that the notion so given is the rudest possible.

Ursa Minor	From N. Pole to Mackenzie River.
Draco	British and Russian N America.
Cepheus	Greenland, Iceland.
Cygnus	N. Atlantic, between coast of America and Azores.
Hercules	W. of N. America, Gulf of Mexico.
Andromeda	Mediterranean, Austria, Spain.
Pegasus	Cape Verd Islands.

Cassiopeia	N and W Europe, Spitzbergen.
Perseus	Caspian, Black Sea, Persia.
Auriga	W. Tartary
Lynx	E Tartary, Japan.
Ursa Major	E Siberia, Sea of Kamscatka, N Pacific.
Camelopardus	W Siberia.
Orion	Ceylon.
Eridanus	Madagascar
Canis Major	Ocean W. of New Holland.
Canis Minor	Borneo.
Hydra	New Guinea
Leo Minor	Ocean E. of Japan
Centaurus	New Zealand and Ocean S. and E
Bootes	Sandwich Isles, and Ocean N. and E
Serpens	Pacific Ocean off Mexico
Ophiuchus	Pacific Ocean off Peru and Columbia
Aquila	Columbia, Peru, River Amazon.
Lyra	United States.
Corona Borealis	Off California
Cetus	Congo, Mozambique
Aries	Egypt, Ethiopia, W. Arabia.
Taurus	E Arabia, Hindostan
Gemini	China, East peninsula of India.
Cancer	Philippines, Ocean off China.
Leo	Ladrone Islands.
Virgo	Society Islands, and Ocean N. W.
Libra	Marquesas to Pitcairn's Island
Scorpio	Easter Island and Ocean S
Sagittarius	Ocean off Chili, Buenos Ayres.
Capricornus	Brazil.
Aquarius	Ocean off Brazil
Pisces	Guinea and interior of Africa.

To return to the projection; it has been objected that the constellations which are near the corners and sides of the cube are divided among different maps. This is certainly *the* failing of the projection: but it must be remembered that every choice which could have been made has some remarkable defect. And the objection lies, not so much against the species of projection, as against the choice of the cube for the exterior figure on which to project But the cube, which is a solid of the least number of faces, renders the disadvantage as small as is possible. Had the maps been broken up into constellations, the same objection would have applied still more strongly, unless each design had been large enough to include not only its constellation, but all around it; so that each constellation should appear in one map as the principal figure, and in several others as contiguous to the principal figure. This is what is done in the atlases of Flamsteed and Bode; and for small portions of the heavens answers very well; but it would very much have increased the expense of these maps. Any projection of the two hemispheres separately would have been out of the question on so large a scale. There appear to be only two ways of meeting the difficulty, and both of them expensive. The first, to suppose the faces of the cube extended, and the projection to be carried farther on each face, so as to get the contiguous portions, which would thus be repeated, some on two, some on three maps; the second, to have another gnomonic projection, in which the sides of the cube should be parallel to the diagonals of the first projection. As the matter stands, we have the advantages;—1. of having great circles represented by straight lines;—2. of getting the circumpolar portion of the heavens very nearly into one map;—3. of representing a whole sixth of the sphere in each map;—4. of drawing the most important part of the zodiac with very little distortion. These must be placed against the disadvantage of not being able to present to the eye *all* the most remarkable groups; which is a defect only for finding the stars by means of one another, and none whatever for most of the other practical uses of the map. We need hardly observe, that there is in each map a sufficient number of groups to diminish the inconvenience materially.

We now come to the question of the constellations. The writings of Ptolemy (who lived about the year 140 of our era) which preserved a full account of all that had been done before him, were the most classical works on astronomy, till the time of Tycho Brahé, or about A.D. 1600. In forming his catalogue of the longitudes and latitudes of the stars, he fixed the relative position of the constellations, and rendered it necessary to keep to his arrangement, because he described each star, not by letters or numbers, but by its position in the constellation. Thus, what we call β Orionis or Rigel, was denominated by Ptolemy, "the bright star in the left foot."

The figures of the constellations are of no use to the astronomer, as such, a star is sufficiently well known, when its right ascension and declination are given; and if letters referring to the constellation are used, such as β in Orion, γ in Draco, &c., it is not now to direct the attention to any imaginary figure of an armed man or a dragon, but to a particular region of the heavens, which might with equal propriety have been called region A or region B. It is to the mythological antiquary that the figures are useful, as sometimes throwing light upon his pursuits. Every ancient people has written its own version of the singular fables which are common to all mythologies, upon groups of stars in the heavens; and it might have been thought that some feeling of congruity, if taste were too much to expect, would have prevented the burlesque of mixing the utensils of modern life with the stories of the heroic age, presenting much such an appearance as the model of a locomotive steam-engine on the top of the Parthenon. But the Lacailles, the Halleys, and the Hevelii, have arranged it otherwise, the waterbearer pours a part of the stream which should wash the southern fish into a sculptor's workshop; a carpenter's rule has got between old Chiron and the altar on which he was going to sacrifice a wolf; and the Lion and the Hydra, whose juxtaposition has made more than one speculator imagine he had found the key to the whole allegory, are in truth two astronomers fighting for a sextant, which Hevelius has placed at their disposal. A great part of the southern hemisphere is laid out in mathematical instruments.

If figures are to be drawn at all, it is, as we have said, for the historian, not for the astronomer; and we imagine the former will think it no loss that in our maps the heavens of Ptolemy have been restored, and in no one drawing exceeded. The names only, and boundaries of the modern constellations, are given; but all the figures are those of Ptolemy, so arranged as to represent his catalogue. Mr Howard, who drew the figures, has favoured us with the following account of the alterations, which he found it necessary to make in the usual distribution of the stars, in order to represent the catalogue of Ptolemy

"The star μ Ceti has been transferred to Aries; it was described by Ptolemy as at the extremity of the hind foot"

"α and θ Crucis have been appropriated to the foot of Centaurus, agreeably to Ptolemy's description of them"

"The river Eridanus is not carried so far to the south-west as the star now bearing the name of Achernar, because the star described by Ptolemy as the last of the river, is placed by him in longitude ♈ 7° $\frac{1}{2}$ $\frac{1}{6}$, and south latitude 53½°, giving a difference of nearly 50° in longitude (with full allowance for precession) and 7 or 8 degrees in latitude"

"The variations I have found necessary in drawing the figures according to Ptolemy's description, are unimportant. A reference to his catalogue will set any question respecting them at rest, as I have adhered closely to it in every instance"

The maps which we are describing, represent the interior of the heavens, that is, the spectator is supposed to stand at the centre of the cube The difference between a map and a globe, generally speaking, is, that in the former the spectator is supposed to be in the inside, and in the latter, at the outside The consequence of this difference is, that when the north pole is uppermost, a spectator who places himself directly opposite to the vernal equinox, sees Aries upon the left hand in the map, and upon the right hand in the globe. When a spectator looks at the equinox (which suppose to be at the south, on the meridian), from east to west is from left to right, and the apparent daily motion is in that direction · but this apparent daily motion brings the zodiac on the meridian according to the order of the signs, and therefore Aries *follows* the equinox, and must appear on the left. On the outside of the globe the effect is reversed, (see page 5) unless we suppose the backs of figures to be presented. The question now arises, did Ptolemy conceive himself to be looking at the constellations from before or behind, from the inside or outside of the sphere? Four different hypotheses are possible, between which, at first sight, it might appear easy to decide, by inspection of the catalogue, but, as we shall presently see, a question has been raised. This much appears certain, that before the time of Bayer, A.D. 1600, all maps were drawn so that the spectator either looked at the *backs* from the *outside*, or at the *fronts* from the *inside* of the sphere To this we have not met with any exception, though we cannot of course undertake to verify such a proposition. Apian's Cosmographia (edition of Frisius, 1553) contains an example of the first, and Postellus'* *signorum cœlestium vera configuratio*, published also in 1553, of the second Bayer adopted another plan, described and reasoned upon by Flamsteed in the following paragraph, which is translated from the preface to the third volume of the *Historia Cœlestis*, p 156.

"Tycho Brahé died in the year 1601, two years after Bayer published his Uranometria, wherein he gives us maps of all the constellations; his figures are tolerable, and the stars well enough laid down according to their places in Tycho's catalogue, and many other small stars are added, which are not in the catalogue of Tycho, and which, it appears, he (Bayer) laid down by the unassisted eye, by comparing them with the fixed stars inserted in his maps from Tycho's catalogue, whose nomenclature is the same But having drawn all his human forms, except Bootes, Andromeda, and Virgo, with their backs towards us, those stars which all before him place in the right shoulders, sides, hands, legs, or feet, fall in the left, and the contrary, in his figures, with which, therefore, whosoever goes about to examine the ancient observations, or the catalogues of the fixed stars printed or published in any language, will find himself much perplexed, if he be not beforehand apprized of this. The reason probably of Bayer's error, was, that often finding the words ἐν νωτῳ and εν μεταφρενῳ in Ptolemy's catalogue, and consulting the Greek Lexicons for the sense of them, he always found νωτος rendered by *dorsum*, and μεταφρενον by *interscapilium*, and concluded that *interscapilium* was the space betwixt the shoulder blades on the back; and whenever he met with either of these words in the description of any constellation, except Virgo and Andromeda, he drew it with the back towards us. Whence he makes all those stars that Ptolemy (and the ancients, and all since them to himself) placed in right

* To our disappointment, this work contains nothing on the point in question, except what is to be found in the map. This was afterwards copied into Morel's edition of Aratus, 1559.

shoulders, arms, sides, legs, and feet, &c., of their forms, to stand on their left, whereby he renders the oldest observations false and absurd. To remedy this fault, when he mentions any eminent fixed star to be *in dextro humero*, or *dextrâ tibiâ*, he adds *alias in sinistrâ*, &c.; which, indeed, seems to correct the misconception, but being done but seldom, will perplex those that make use of his maps, and render them useless. Had Bayer but drawn the map of Sagittarius, or any other of the human forms, so that the stars placed in the right hands, shoulders, sides, and feet of Ptolemy's catalogue might stand on the same in his figures, he would have seen that they would all have their faces towards us, and thereby would have learned, that in Ptolemy's Greek, *νωτος* signifies the *crates corporis*, or the ribs, and *μεταφρενον*, the space betwixt the shoulders, not only on the back, but also on the forepart of the body or upper part of the breast, and there would then have been no incongruity between his figures and ancient descriptions. I am convinced that not only Ptolemy but Homer himself uses those words in a more comprehensive sense than the Lexicons commonly allow. Nevertheless, in most of the maps of the fixed stars that have been engraved since those of Bayer, the forms are taken from him, and have the same faults with his."

It so happens, that owing to stars being frequently referred to the shoulders, or to some part of the dress, as Orion's belt, which will equally apply to the front or hind part, the back is very seldom directly mentioned, but when such a necessity does arise, the word *νωτος* or *μεταφρενος* is used, which (though Flamsteed, without citing any authority, curiously enough supposes them to mean the front, being led away by his hypothesis) are always used, the first for the back generally, the second for the part of the back between the shoulders. To draw a correct inference, we must remark, that since the supposition of an inside view of front figures makes the heavens agree with Ptolemy's description as to the right hand or left hand position of any star, it is plain that Ptolemy placed the figures fronting inwards on the sphere. Whether he supposed himself to look from the inside or outside, must be settled by ascertaining whether he places stars which are in the middle of the figure in the front or in the back; and the preceding words prove that he did the latter. Bayer, therefore, should have reversed the order of the constellations, making the signs of the zodiac proceed from left to right, instead of from right to left, at the same time when he made the other change We have already mentioned that in the gnomonic projections which have preceded the present, and we may add, in most maps of the seventeenth century, the plan of Bayer has been followed, that is, an inside view of figures fronting outwards. The same plan has been adopted in our maps; not with any view to correctness, but with an avowed departure from it, and for this reason, that an inside view of the sphere was too essential to astronomical purposes to be sacrificed to historical and mythological truth But at the same time, in choosing between the reversal of right and left, or front and back, the former has been preferred, as being a less violent departure from the actual appearances which Ptolemy supposed himself to observe when he formed his catalogue. We may sum up the result in the following *memoranda* —

I Ptolemy took an outside view of figures fronting inwards; our maps are an inside view of figures fronting outwards, therefore the left hand of a figure in our map is the right hand according to Ptolemy, and *vice versâ.*

II To obtain a representation of the sphere of Ptolemy* in every respect, look at the maps *through the paper*

In the cube of page 20, that we might present to the student

* It has been suggested to us, that Ptolemy himself placed some constellations differently from others, that is, some presenting the front and some the back: and Virgo is particularly instanced, in which one star (*ο*) is described by him as being in the *countenance* (*προσωπον*). But in this constellation, as in all others, the "right" and "left" of Ptolemy can only be drawn upon a figure fronting inwards, while the star (*ο*) can be placed in the countenance, to a person looking from behind, if the face be turned sideways, as in the map The placing of stars in the wings of Virgo is to us a strong presumption that the back of the figure was looked at our readers must have observed the awkward manner in which those appendages are obliged to be brought forward when the front of the figure is drawn in the usual way On this very point, Ptolemy mentions his having removed some stars from the wings to the sides, to preserve the natural appearance of the figure Would he have thought one position more natural than another had the wings been in front? The reader may decide for himself, and perhaps the more safely (if we may say it), that the question is not how ladies would have worn their wings, had they them, but how a mathematician would have thought they ought to have worn them

Hipparchus expressly says, that *every body* turns *all* the constellations towards the inside of the universe (*Petavius, Uranologion*, p 181) But we cannot ascertain how he supposes them to be looked at, whether from the outside or inside.

maps in every respect like those which this treatise accompanies, without raising a question which was there of no importance, we have drawn such maps on the *outside* of the cube To set this right, and to make the cube there given a perfect *outside* representation of the sphere, write ♎ where ♈ is now, all the rest of the figure remaining the same

The longitudes of the stars have been altered more than 20° by *precession* since the time of Ptolemy, by which means their position with respect to the equinox, is very different from what it was in his day. In noticing this inequality, we shall also include those of *nutation*, *aberration*, and *refraction*, by which the apparent places of the stars are also affected, as well as *parallax*, which alters the places of the planets That is, we shall explain the nature of the *phenomena* without entering into their causes

Let the stars only be laid down on an immoveable wooden globe, which is placed inside a glass globe. On the glass globe draw the circles of right ascension and declination, and let an axis pass through the poles of the ecliptic On this axis let the glass globe turn slowly and uniformly round, in the direction contrary to that in which the constellations of the zodiac are reckoned, at the rate of about 1° in seventy-two years This motion of the circles by which right ascension is measured, is the effect of a slow conical motion of the earth's axis. It changes the right ascension and declination of stars, and also their longitude, but not their latitude; because the pole of the ecliptic keeps its position, and the latitude is what the angular distance from the pole of the ecliptic wants of 90°. If we suppose the exterior glass globe to remain fixed, the same relative change will be produced by causing the interior globe to revolve round the pole of the ecliptic in a contrary direction, that is, according to the order of the signs. This will make every star move slowly forward along its parallel of latitude, which is the most simple way of stating the phenomenon This is called the *precession.*

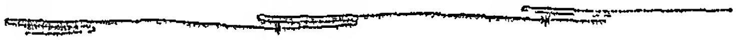
While the glass globe above mentioned is revolving round an axis which passes through the poles of the ecliptic, let this axis itself (its centre remaining fixed) make a very minute conical oscillation of about nineteen years in duration. The effect will be that the parallel of latitude will not merely move along over the star, but will have a lateral motion, which will make it oscillate to and fro, being first on one side of the star, then on the other. If the motion be caused by the interior globe, the effect will be that the star, instead of moving along its parallel of latitude, will describe a waving curve, to which the parallel of latitude is a sort of axis The effect of this is called *nutation*, and the utmost departure of the pole of the ecliptic from its mean place is about 17″. It arises from the axis of the earth not describing merely a cone, but a cone fluted from the vertex to the base

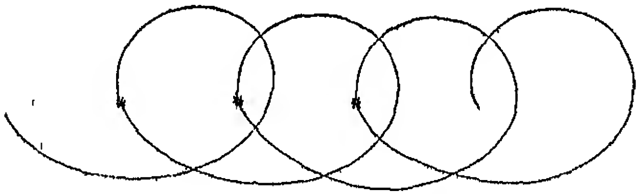
While the exterior glass globe is performing the two motions above described, let the stars on the interior wooden globe move on that globe in the following manner:—

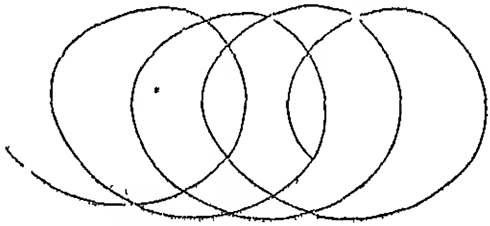
Let a star in the ecliptic oscillate backwards and forwards in the ecliptic, through an arc of about 40″ in the course of a year At the pole of the ecliptic let the star which has hitherto been in the pole, describe a yearly circle of 20″ of radius about the pole. Between the two let the star describe a yearly ellipse whose greater radius is 20″, and is parallel to the ecliptic, and more or less flattened according as the star is nearer to, or farther from the ecliptic; as is shown in the preceding figure. The alteration of place arising from this motion is called *aberration*, and arises from the motion of the earth, which produces an alteration of the apparent direction of the rays of light which meet the eye; being a phenomenon of the same kind as the alteration of the apparent direction of a ship's course, when seen from another ship which is in motion. If we suppose the star to move in consequence of precession and nutation, as in the second supposition of the preceding descriptions, the effect may be represented as follows. Instead of supposing the star to describe the waving curve alluded to along its parallel of latitude, let the centre of the ellipse of aberration describe that curve. Let the ellipse always present its flat part to the pole of the ecliptic, and let the star describe the ellipse in the course of a year.

Refraction is the effect of the atmosphere upon the rays of light, by which they are bent a little towards the earth, in consequence of which the star appears somewhat higher than it really is. At the horizon, where it is greatest, it is somewhat more than half a degree, at the zenith it is nothing; and of any two stars, that is the most altered by refraction which has the least altitude Owing to the difficulty of laying down the horizon on our maps, it is not easy to represent the effect of refraction upon them

The preceding complicated motions cannot be well understood by any but a mathematician; it is evident that the three, precession, nutation, and aberration, will sometimes conspire, or each increase the effect of the other, and sometimes destroy each other's effects either wholly or partially The following figures show the species of waving curve in which four different stars describe their parallels of latitude The first is that of δ Orionis, the second that of α Leonis or Regulus, the third that of the Pole star, and the fourth that of γ Draconis







The nutation, from its smallness, and the length of its period, is insensible on the scale which we have chosen. The effect is therefore entirely that of aberration and precession. In γ Draconis, which is near the pole of the ecliptic, and, in which, consequently, the precessional motion is small, and the aberrational nearly circular, we see the effect of a circular motion, where the circle is slowly carried forward But in Regulus, which is nearly on the ecliptic, and on which the effect of precession is large when compared with that of aberration, the latter being little more than a linear oscillation, the effect is very different. In δ Orionis, which is not near either to the ecliptic or its pole, we see a mixture of the preceding characteristics. The first two stars have three years' motion represented, and the latter two, four years.

Parallax is one of those effects which are not easily laid down on the maps, owing to their dependence upon the horizon All astronomical tables are made to represent the appearances of the heavens from the *centre* of the globe, whereas the spectator is at its *circumference.* Imagine two persons with telescopes, one at the centre, the other on the surface, the intervening ground being supposed transparent. To see a star in the zenith, both must point their telescopes the same way, viz., directly upwards; but to look at a star in the *horizon of the surface,* or between that horizon and the zenith, the spectator at the centre must point his telescope higher than the one at the circumference. The difference of the directions of the two telescopes is the parallax of the star. It is greater, the nearer the object looked at; for the fixed stars, it is totally insensible, on account of their distance, and equally so on our maps, for all the bodies of the solar system except the moon, for which it is sometimes greater than a degree. For the sun it is about eight seconds and a half.

CHAPTER IV

VING explained the constiuction on which these maps of the sta drawn, we now pioceed with the description of the manner ch they have been filled up, and subjects connected with it.

When we speak of maps of the heavens, it must be, in some wi other, under limitations such as accompany oui notions of ma the earth To make an absolute delineation of the latter is ir sible the size of the paper imposes the necessity of introducin ly such objects as are of a visible magnitude in the scale which osen. If we had to consider physical geography only, the be inciple which we could adopt, supposing theie were means irying it into practice, would be to suppose the spectator plac such a height above the surface, that the country which he is ap should be as much undei his eye, and appear of about the sar ze, as the paper on which he is to draw it. If in such a ca lerably distinct vision could be procuied, the minor features of t ndscape would disappear, and the ielative importance of tho hich remain could be estimated We have a map of this sort ie drawing of the face of the moon, as seen through a powerf elescope

But for the purposes of political geography, such a map wou equire considerable additions Rivers too small to be seen are t oundaries of powerful states, and towns which could not be omitt would be altogether imperceptible. These two considerations ha heir analogies when we come to maps of the heavens. If we we to propose maps of the visible heavens, it would be necessary first ascertain what they are On a hazy night they are not the same on a clear night; and even at the same hour and place, the eye one man will distinguish objects which have no existence in that another Still greater will be the difference, if we suppose one have a telescope, which the other has not · the heaven of a twent foot reflector is *toto cœlo* different from that of the naked eye, or ev of a toleiable refractor. It might be, and has been, proposed, to ada maps of the heavens to some given telescope—say, for example refractor of five-feet focal length, with a magnifying power, say of two hundred times But even this would be no certain criterion, for instruments of different makers, and different instruments by the same maker, have different degrees of goodness, while different people will discern more or less with the same instrument. As a rough guide to the selection requisite for utility, such a test might be taken; but it would be far from accurate near the limits.

Again, historical or practical considerations may invest a very faint object with an interest which does not attach to much brighter ones; and the position of a small star in the heavens may render it of more importance than many of greater popular fame Were the astronomer to choose, he would rather the whole constellation of Orion were annihilated than lose the pole star, and γ Draconis, both as passing near the zenith of Greenwich, and as being the star by means of which aberration was discovered, is of much greater interest than Sirius, the brightest star in our heaven. Let it happen that a little star of the eighth magnitude is predicted to lie almost directly in the apparent track of a coming comet: it immediately becomes of much greater importance to determine the place of that star very accurately, than of dozens which could be named, and which are always visible; for the most powerful telescopes are seldom furnished with any very exact means of finding the place of a star in the heavens, but are provided with *micrometers*, which serve to ascertain the relative position of two objects so near each other, that they appear in the field of the telescope together. Hence the place of the small star being settled, and that of the comet with respect to it, the absolute place of the latter is found.

From such considerations, it appears that some test must be found of a more practical character than any yet named; and when we consider that any method will include the stars visible to the naked eye, and even to inferior telescopes, it is obvious that the difficulty at the limits is a matter which entirely concerns the possessor of a good telescope, and no other person, except inasmuch as he may not like to have his maps crowded with objects which he cannot see. But even of these there are many of which he must read: so that the only question is—1. How to lay down a sufficient number of objects of interest or high curiosity:—2. How to enable him to draw a line between those which exist with reference to his astronomical means, and those which do not?

But for the astronomer, it is necessary to lay down, for the most part at least, such objects as have been observed, and actually find a place in his books of reference. A new object is seen, and the first question is, of all those which lie near it, which have had their places well determined? where is he to look for information respecting them? This is much the same as asking—By whom have they been observed? in what catalogue are they found? Hence it becomes most requisite that all maps of the stars should be based upon some one or more of the best catalogues. If there should even be visible stars (of which there are several) which do not find a place in any of the standards of astronomy, they would be of little use. Nothing could be very accurately determined by them, for they are not very accurately known themselves. The interest which belongs to peculiar portions of the heavens—the zodiac, for example, which always contains most of the planetary bodies—has caused them to be more carefully noted than the rest. This will make catalogues rather standards of astronomical importance in reference to stars which they insert or omit, than of comparative visibility. But this is precisely what is desirable on account of the astronomer; and, as we have observed, it is of little consequence to any one else what method is chosen.

Astronomical catalogues are of three kinds:—

1. Those which are intended to give the places of the stars contained in them with the utmost degree of accuracy which the existing state of astronomy will admit: these, as may be supposed, cannot contain a great many stars. That of Dr Maskelyne, published in 1805 (and then considered the most correct which had appeared), contained only thirty-six stars. This number was afterwards increased in the Nautical Almanac; and at present the places of one hundred stars are yearly given in that work, of which fifty-four have the standard character here described. As these must be considered, for every practical purpose, what they are called in the Nautical Almanac, the "principal fixed stars," we give a list of them, the standard stars being in *italics*. They are in order of right ascension, and the numbers refer to the hours of right ascension:—

0

γ *Pegasi* (Algenib).
β Hydri.
α *Cassiopeæ*
β Ceti.

I

α *Ursæ Min.* (Polaris.)
θ[1] Ceti.
α Eridani (Achernar.)
α *Arietis.*

II.

γ Ceti.
α *Ceti.*

III

α *Persei.*
η Tauri.
γ[1] Eridani.

IV.

α *Tauri* (Aldebaran)

V

α *Auriga* (Capella.)
β *Orionis* (Rigel.)
β *Tauri.*
δ *Orionis.*
α Leporis.
ε *Orionis*
α Columbæ
α *Orionis.*

VI.

μ Geminorum.
α Argus (Canopus,)
51 (Hev.) Cephei.
α *Canis Maj.* (Sirius)
ε Canis Maj.

VII.

δ Geminorum.
α[2] *Geminorum* (Castor)
α *Can. Min.* (Procyon)
β *Geminorum* (Pollux)

VIII.

15 Argus.
ε Hydræ.
Ursæ Majoris.

IX.

ι Argus.
α *Hydræ*
θ Ursæ Majoris.
ε Leonis.
α *Leonis* (Regulus)

X.

η Argus.
α *Ursæ Majoris.*

XI.

δ *Leonis.*
δ Hydræ et Crateris.
β *Leonis*
γ *Ursæ Majoris.*

XII.

β Camæleontis
α[1] Crucis.
β Corvi
12 Canum Venaticorum.

XIII.

α *Virginis* (Spica.)
η *Ursæ Majoris.*
η Bootis
β Centauri.

XIV.

α *Bootis* (Arcturus.)
α[2] Centauri.
ε *Bootis.*
α[2] *Libræ.*
β *Ursæ Minoris.*

XV.

β Libræ.
α *Coronæ Borealis.*
α *Serpentis.*
ζ Ursæ Minoris.
β[1] Scorpii.

XVI.

δ *Ophiuchi.*
α *Scorpii* (Antares.)
η Draconis.
α Trianguli Australis.

XVII.

ε Ursæ Minoris.
σ Octantis.
α *Herculis.*
β *Draconis*
α *Ophiuchi.*
γ *Draconis.*

XVIII.

μ[1] Sagittarii
δ *Ursæ Minoris.*
α *Lyræ* (Vega.)
β *Lyræ.*
ζ *Aquilæ.*

XIX.

δ *Aquilæ.*
γ *Aquilæ.*
α *Aquilæ* (Altair.)
β *Aquilæ.*

XX.

α[2] *Capricorni.*
α Pavonis.
λ Ursæ Minoris.
α *Cygni.*
61[1] *Cygni.*

XXI.

ζ Cygni.
α *Cephei.*
β *Aquarii*
β *Cephei.*
ε Pegasi.
α *Aquarii.*
α *Gruis.*

XXII.

ζ Pegasi.
α *Piscis Australis* (Fomalhaut.)
α *Pegasi* (Markab.)

XXIII.

ι Piscium
γ Cephei.
α *Andromedæ.*

With the difference between the more exact catalogue and the second-rate one, the maps have nothing to do, for the quantity in question is inappreciable. A few hundredths of a second in the time of coming on the meridian, is all the difference of errors that is found by observation to exist between the first and second-rate stars of the preceding list.

2. Catalogues which are intended to represent a large portion of the heavens with considerable accuracy, but not with that high degree which it is possible to obtain by multiplying observations of the same star. Such catalogues are always more than sufficiently exact for the purposes of a map.

3. Catalogues of objects which are interesting, not as marking out definite points in the heavens, but on account of the phenomena which they present, whether of a fixed, periodical, or indefinitely changing character. Such are double and triple stars, variable stars, and all the class of nebulæ. The exact places of these being a matter of no great importance, only such right ascensions and declinations are given as will enable the observer to find what he wishes to look at. But even these are sufficiently exact for the purposes of a map, in which the whole field of a telescope is but a very small circle.

So soon as the order of the maps has been settled, as to what stars or other objects they shall contain or omit, it becomes necessary to fix upon an epoch The small motion of precession, described in p. 64, is continually varying the absolute positions of the stars with respect to the equinox, or of the equinox with respect to the stars But this motion, amounting to only a degree in seventy-two years, does not affect the utility of the map, as a map, for that time at least, and even at subsequent periods may cause it to be a useful history of the past state of the heavens. The time will come when the pole-star is no pole-star at all, for any of the purposes which it now assists; but such a change must be the work of thousands of years, and need not be taken into account. In some degree, to obviate future inconveniences, the maps in question represent the heavens as they will be in the year 1840—so that till that time they are in fact changing towards exactness. In 1858 the equinox will be wrongly placed by about a quarter of a degree; in 1912 by about a whole degree.

The *identification* of the several stars is the next point to be considered If the student in astronomy should imagine that every possible star is distinctly laid down in some catalogue or other, he would be very much mistaken. The stars he finds catalogued are for the most part those which are visible to the naked eye, or to telescopes of moderate aperture.* But every accession of optical power makes the heavens present new stars and nebulæ, to an extent which human industry can hardly be expected to classify. The Berlin Academy, in 1825, invited all such astronomers as were inclined, to share among them the task of making minute maps of the heavens. It was proposed that each of twenty-four observers should take one hour of right ascension; and "that, having formed a chart including all the stars of the *Histoire Céleste* and Bessel's Zones, he should put in, by estimation only, all the stars that could be seen by one of Fraunhofer's telescopes of thirty-four lines aperture" A few of these charts have been published: the stars of course have no names, nor any other method of identification, except their place in the map, which looks like a spoiled skeleton of a map plentifully spirted with small drops of ink We have thus, besides the stars which are in catalogues, a large reserve of additional points of reference, which come, one and another, into use when a comet or a planetary body passes by them. An observer compares a comet or planet with a small star, which he finds conveniently in the field of his telescope with the comet or planet He can, with the micrometer, settle the position of the comet with respect to the star, much better than he can settle that of either star or comet in the heavens. To make this clearer, observe that most astronomical instruments may now be considered as divided into two classes†—*meridian* and *equatorial* The first have telescopes which move in the plane of the meridian only, as their name imports · they are incapable of any lateral or azimuth motion (except a very small quantity, to allow of the proper adjustment of the instrument), and consequently

* The focal length of a telescope is the distance of the focus of the object-glass from the glass itself; but as the eye-glass is very near the focus of the object-glass, the focal length may be taken for the length of the telescope itself.

† The *zenith sector*, for observing stars near the zenith, and the *altitude* and *azimuth* instrument, which resembles the theodolite in principle, are now not so much used.

only see a star for about a minute before and after it comes to the meridian. The object of this fixed character is stability, it being found that every motion of which a telescope admits opens two or three sources of error Even with such precautions, no meridian instrument can, without verification, be considered as perfectly the same for twenty-four hours together; and it is the business of the astronomer to make such observations as will, by comparison or combination, point out or do away with the instrumental errors. And if even meridian instruments are thus to be in a continual state of correction, which are of the most simple construction, mechanically speaking, still less can *equatorial* instruments be made the *direct* means of setting the places of heavenly bodies. These are to be so constructed, that the telescope may, by the mere motion of the hand (or which is now preferred, by clockwork), be made to follow any star in the heavens throughout the whole time during which it is visible There must be then an axis parallel to the axis of the heavens, both ends being pivots of rotation. Off this axis must come another axis perpendicular to it, on which the telescope must turn. An *hour-circle* must be connected with the principal axis, which may point out nearly at what period of the rotation the telescope is for the time being; and a *declination circle* must be fixed to the cross axis, on which it may be seen how much the telescope is elevated above the position in which (if the instrument be true) it should look at a point in the equator. If all the preceding conditions be fulfilled, and the telescope be once pointed on a star, a slow motion given to the principal axis will make the star remain visible. But these instruments cannot be so constructed that they shall accurately give the absolute right ascension and declination of a star, on account of the variety of conditions to be fulfilled, and other circumstances; but they can be so constructed, that the hour and declination circles shall be sufficiently exact to find a star, and place it somewhere in the field of the telescope. When two objects are together in the field, a micrometer may be applied, to give very accurately the *relative* positions of the two.

The accurate determination of the places of stars and planets by large fixed instruments is the proper work of public observatories while the determination of such relative measurements as can be made by equatorial instruments is not only the course in which a private observer can make himself most useful, but also that in which astronomy presents itself in the most interesting light to the greater part of mankind. But the object of this digression has been the manner in which the uncounted class of unknown stars become useful. An observer, perhaps many thousand miles from a first-class observatory—say in South America—makes a series of observations upon a comet with an equatorial instrument, not by absolutely determining its place, but by comparing it with a number of unknown stars, whose places he finds with sufficient nearness to enable others to identify them. Say, for instance, that August 13, at 22^m 47^s past ten in the evening, he has found that a comet is in the field with a small star, whose right ascension is* (as near as his instrument will show) 13^h 20^m 8^s, and its declination 20° 15′ 48″ N. By accurate micrometrical observations, it is ascertained that the comet has 17^s, 3 more of right ascension than the star, and 23″ less of declination. This is transmitted to Europe; and by the more powerful aids which large observatories contain, a small star is detected very near the place in question (such as would be visible to the foreign observer, according to his own description of his optical means), and this same small star, being accurately measured, is found to have a right ascension of 13^h 20^m 41^s 5, and a declination of 20° 16′ 2″. Consequently, the apparent right ascension of the comet, at the time and place in question, was 13^h 20^m 58^s, 8, and its declination 20° 15′ 39″. The use of the Berlin maps, when completed, will be, 1. That the disappearance of any stars will be detected, if the process be repeated at intervals;—2. That when any unknown star is made a point of reference, as in the preceding supposed observation, a look at the map may at once give the *observatory* astronomer assurance of the star being really there, and not so contiguous to another as to make it doubtful which to observe.

* Such right ascensions and declinations are usually put down with as much appearance of accuracy as if it was really meant to be implied that the instrument used was fit for such close determinations. The reason is, that since all which is known is that the instrument will be wrong, but not which way it will be wrong, whether in excess or defect, any alteration for the sake of round numbers might be an increase of the error.

enable him to draw a line between those which exist with reference to his astronomical means, and those which do not?

But for the astronomer, it is necessary to lay down, for the most part at least, such objects as have been observed, and actually find a place in his books of reference. A new object is seen, and the first question is, of all those which lie near it, which have had their places well determined? where is he to look for information respecting them? This is much the same as asking—By whom have they been observed? in what catalogue are they found? Hence it becomes most requisite that all maps of the stars should be based upon some one or more of the best catalogues If there should even be visible stars (of which there are several) which do not find a place in any of the standards of astronomy, they would be of little use. Nothing could be very accurately determined by them, for they are not very accurately known themselves. The interest which belongs to peculiar portions of the heavens—the zodiac, for example, which always contains most of the planetary bodies—has caused them to be more carefully noted than the rest This will make catalogues rather standards of astronomical importance in reference to stars which they insert or omit, than of comparative visibility But this is precisely what is desirable on account of the astronomer; and, as we have observed, it is of little consequence to any one else what method is chosen.

Astronomical catalogues are of three kinds:—

1. Those which are intended to give the places of the stars contained in them with the utmost degree of accuracy which the existing state of astronomy will admit: these, as may be supposed, cannot contain a great many stars. That of Dr Maskelyne, published in 1805 (and then considered the most correct which had appeared), contained only thirty-six stars. This number was afterwards increased in the Nautical Almanac; and at present the places of one hundred stars are yearly given in that work, of which fifty-four have the standard character here described. As these must be considered, for every practical purpose, what they are called in the Nautical Almanac, the "principal fixed stars," we give a list of them, the standard stars being in *italics* They are in order of right ascension, and the numbers refer to the hours of right ascension:—

had been preceded by Alexander Piccolomini,* who in his book *Della Sfera e delle Stelle fisse,* has carried the principle which Bayer's fame is founded upon further than his successor: for he has abandoned the pictures in favour of letters. As this is an historical point † of some curiosity, we shall in the note extract the passage in which he explains his views. Bayer himself afterwards abandoned letters in favour of numbers, in the joint edition ‡ of himself and Julius Schiller, but notwithstanding this rejection, (which indeed was not known, as it has never been very distinctly stated in modern times that Schiller's edition was in reality the work of Bayer, as to the astronomical part, §) Flamsteed and the more modern astronomers have agreed in using the letters of Bayer, though not without some mistakes and misapprehensions.

* Alexander Piccolomini, born at Sienna, 1508; died there, 1578. He was Archbishop of Patras, and *coadjutor* of Sienna, and was the first Italian who wrote on mathematical and philosophical subjects in his native language. He has also some reputation as a comic writer. The first edition of the book cited in the text bears, in the preface, *Da la Villa di Valzanzibio. Il di X di Agosto nel* MDXXXIX. See Riccioli, Vossius, Bayle, &c. There is a full account in the *Elogi degli Uomini illustri Toscani, Lucca,* 1771.

† Voglio che sappiate ancora che queste stelle, che io u'ho detto, piu principali, e piu chiare, che io considero fino alla quarta grandezza; tutte ho notate à i piedi de le fauole di qual si uoglia immagine, ho notato dico, ciascheduna con una lettera de l'alfabeto. e questo ho fatto, accioche poi ne le figure le riconosciate, e sappiate distinguere l'una da l'altra, poniam caso, quella che sarà ne la testa, da quella che sarà nel braccio, e cosi de l'altre parimente. Ben è uero, che poi ne le figure ho posto molte uolte alcune stelle piu, lequali a i piedi de le fauole non ho numerate. e conseguentemente tali stelle non son notate con lettera d'alfabeto. e questo ho fatto perche per la breuità de la carta, tanta moltitudine di caratteri de l'alfabeto farebbe in molte figure non poca confusione ma ho auertito di far questo in quelle stelle, lequali facilmente possa considerarsi in che parte sieno de l'immagine, per la uicinanza di alcuno altro con il caratter notato: come il tutto benissimo comprenderete, senza che io piu in ciò mi distenda. Ancora non ho uoluto come fa Igino ne le dette figure dipingere i membri di quegli animali, che i Poeti han finto esser nel Cielo, perche ancor che ciò facesse alquanto di uaghezza a l'occhio, nondimeno offuscarebbe ancor parimente le stelle, e farebbe non poca confusione ed io ho piutosto uoluto haver riguardo a la chiarezza de la figura, che a la uaghezza de l'occhio; essendo il mio primo intento, mostrar quelle figure piu distintamente ch'io posso, e nel modo che le sono, sendo elle sol di stelle adornate senza braccia ne piedi, come ciaschedun puo uedere.

‡ See PENNY CYCLOPÆDIA, Article BAYER.

§ Schiller himself, Riccioli and Gassendi, state it distinctly. See PENNY CYCL. cited above.

After the catalogue of Flamsteed was published, which contained both the old nomenclature of Ptolemy, and that of Bayer, it became the practice to adopt a numbering for the stars in different constellations, derived from the position in which they stood in Flamsteed's catalogue Thus the star γ Geminorum, described by Ptolemy as in the left foot of the second twin, happens to be the twenty-fourth star in the constellation in Flamsteed's catalogue. It is therefore called 24 Geminorum, and generally speaking, when a number precedes a star, the number in Flamsteed's list of the constellation is intended. In Piazzi's catalogue a different method is adopted: the stars in each hour of right ascension are numbered according to the order in which they come on the meridian, without reference to the constellation in which they are. Thus if the 25th of all the stars of Piazzi which are in the fourth hour should happen to be a star in Gemini, it would be the 25 Geminorum of Piazzi, namely, a star in Gemini, not the 25th of the constellation, but the 25th of the stars which have (or had) between three and four hours of right ascension. The stars in the catalogues of Hevelius, Bradley, and Lacaille, have also their numbers, and the consequence is, that the whole system of nomenclature of the stars is in a state of great confusion, with the agreeable certainty of its being almost impossible to introduce one general and uniform system throughout Europe. The only method at present appears to be to attach to the numbering some abbreviation or other conventional distinction for the name of the numberer In the Index to the Astronomical Society's Catalogue, an easily remembered alliteration is adopted: *Bradley's* numbers are in *brackets*, and *Piazzi's* in *parentheses*. Those of Lacaille have the letter C; those of the late Mr. Fallows have Fa. It is not difficult to foresee that all this confusion of nomenclature must increase until it becomes a matter of first-rate astronomical importance to agree upon the use of some general method; and then, laborious as the task will be, it must be accomplished To add to the difficulty, constellations which are used and alluded to by some, are not recognized by others.

With the maps, however, these difficulties have nothing to do, except as they render extreme accuracy of description very difficult, and multiply the chances of error. An inquirer who has occasion to look for a star in the map which he has found in the heavens, will, when he finds it, see its proper description annexed. It matters nothing to him what 24 of Hevelius, or 29 of Flamsteed, really means. it is sufficient that there is a star which will be understood by astronomers under that name, and that he knows which star it is. Another, who wants to find out in the heavens the star called 24 Geminorum of Flamsteed, must have settled, previously to coming to the map, the way in which he is to denote his star; and though he may have encountered a difficulty, he will, of course, have met with it in a manner for which no map can be responsible.

The *magnitude* of a star is a term used to denote its apparent brilliancy. Before the invention of the telescope, the stars were imagined to be bodies of sensible apparent magnitude, as indeed it is obvious they seem to be. And it was an unanswerable argument against the probability of the Copernican system, that, admitting (which was necessary to be supposed) the fixed stars to be so distant that the earth's whole orbit would appear no larger than a point to them, their apparent magnitude made it necessary also to suppose that the largest of them, at least, were many times the diameter of the earth's orbit in diameter. The telescope showed that the appearance of *magnitude* was altogether illusory, and dependent upon atmospherical phenomena; for though upon hazy or troubled nights stars may appear large, their magnitude is not permanent, but accompanied with a tremulous, boiling, or bubbling outline. And in good climates and still nights, no micrometer will give a sensible outline and apparent diameter to any but large stars. That these do appear of some slight sensible magnitude in large telescopes may be true; but it may be shown from the laws of optics, that not even a mere point, supposed to emit light, could be made to appear as nothing but a point, in a lens with spherical glasses at least. The term magnitude then merely denotes brilliancy to the eye, and is itself perfectly indefinite. We see without a glass some five or six gradations of light in the several stars Those of the brightest class are said to be of the first magnitude; those in the next set, which differ sensibly from those of the first magnitude, are said to be of the second, and so on. Telescopic research has detected stars which should be called of the sixteenth magnitude; but as to the fainter objects, it must be observed that not only will different observers assign different magnitudes to the same star, but even the same observer on different nights And many stars which to Bayer appeared brighter than others, do not do so now; but owing to the uncertainty of the denominations employed, it is impossible to say whether this proceeds from a slow change in the brilliancy of the star, or from difference of circumstances and habits of perception in the observers There are now various means of estimating the apparent brilliancy of different stars, that is, their relative brilliancy. Sir J. Herschel, from his father's experiments, estimates the quantity of light received from the several stars which bear the first six magnitudes to be in the proportions of 100, 25, 12, 6, 2, 1: from his own, he rates the light of Sirius at about 324 times that of a star of the sixth magnitude. (Astronomy, *Cabinet Cycl*, p. 375.)

It is sometimes attempted to subdivide at least the greater magnitudes, and to talk of a star of the 2½ magnitude, and so on. It was usual to call a star which was considered as half-way between the second and third magnitudes, one of the 2.3 magnitude. but Mr. Baily, in his edition of Flamsteed's Catalogue, lately published, has adopted the fractions of magnitudes, and it is to be desired that the example should be followed. The following will show that it is not likely two observers with different telescopes * could expect to agree within half a magnitude by mere estimation. Sir J. Herschel (*Mem Astron Soc.* vol. iii. p. 180) compared a large number of the magnitudes assigned by himself to stars with those assigned to the same stars by Professor Struve in his Dorpat Catalogue. Taking an average for each sort of magnitude, it would appear that the stars designated as having the magnitudes in the first column by Professor Struve, would be styled as in the second by Sir J. Herschel; (the second column is in magnitudes, and tenths of magnitudes.)

* It is found that two different persons with the same telescope make up two different instruments, and the discrepancy is still more increased when different telescopes are used, in different climates, or on different nights.

S	H	S.	H
4	5·4	8½	9·5
5	6·5	9	10·3
5½	7	9½	10·8
6	7·1	10	11·1
6½	7·4	10½	12
7	8·1	11	11·5
7½	8·8	11½	11
8	9·0	12	12·7

It appears, therefore, that a mass of estimations by two observers, both accustomed above others to this class of researches, not only produces results considerably different in quantity, but presents absolute inversions of order in the case of the smaller objects. That the difference depends on climate is not probable, since it would also affect the well-known and admitted stars to which the others are referred: for example, Sirius is of the first magnitude all the world over, whether in an English or Italian sky. But whether climate does act or no, this much appears clear, that the method of naming magnitudes by estimation is not a sure method of obtaining a universal classification.

The reader would probably not be wrong in considering the matter thus. If a person used to look at the heavens were to assert that he had seen a comet like a star of the first or second magnitude, it is probable that he would be correct. If of the third, the comet might be concluded to be somewhere between the 2½ and the 3½ of all the recognized stars in the heavens; if of the fourth, between the 3 and the 5; if of the fifth, between the 4 and the 6, and so on. With regard to the maps, we need only observe that the stars are designated after the best catalogues. The only experimental methods of determining the relative quantity of light transmitted by different stars give vague determinations, not fit for settling the questions above treated with any degree of accuracy. In the telescope, a contingent circumstance affords a method of comparing faint objects somewhat better than naked estimation. The measuring instrument itself is not the telescope, but certain very fine threads, (frequently of spider's web,) fixed or movable, according to the nature of the observations to be made, and placed in or near the focus of the object-glass. The image of the star is formed in the focus of the object-glass, in or near the plane of the threads, and the eye-glass may be considered as a microscope, for magnifying the image, and (a defect which cannot be helped) the threads, or *wires*, as they are termed. These wires cannot be made visible without more light than comes from a small star, to remedy which there is an orifice near the middle of the tube, close to which a lamp is placed, the light of which is reflected upon the wires, and the field is thus illuminated The orifice can be expanded or contracted, or closed altogether, and thus the quantity of illumination may be varied Now when two objects are so faint that the illumination of the field may be made to extinguish them altogether, it may be ascertained what quantity of illumination is just sufficient to destroy each, and thus a notion (not a very perfect one) may be formed of the quantities of light received from each. But it must be observed, that it is not only difficult to get a lamp which shall always yield light of the same intensity, and to know whether any given lamp be such or not; but as the various lights of the heavens are almost always more or less of different tints, the same lamp will extinguish one star of one colour sooner than another of the same brightness but different colour. Thus a red light would entirely extinguish a star of the same tint, before a weaker, but bluish star, had disappeared. It is by no means impossible that a diligent employment of lights of different colours might be made to add to our knowledge of this part of astronomy, and it is in such fields as the preceding that the private observer may become a useful assistant to the public one. It would be of little use for an individual to erect an observatory with fixed instruments, for the purpose of obtaining right ascensions and declinations, unless he could give up so much time, and procure such a quantity of assistance in reducing observations, as would place him on a level with national observatories The following account of the late Mr. Groombridge* will illustrate our meaning:—

"In the year 1806, he became possessed of a splendid transit circle of four feet diameter, (the workmanship of our celebrated

* Annual Report of the Royal Astronomical Society for 1831. His catalogue is stated to be in course of publication by the Lords of the Admiralty.

Troughton,) so well known by his name, and the excellent use to which he applied it; and he immediately commenced the task of forming an exact catalogue of the stars as low as the 8.9 magnitude, within 50° of the North Pole

"In this arduous undertaking he persevered with singular assiduity for ten years, and in the year 1816 had completed about 30,000 observations in right ascension, and the same number in declination, on this part of the heavens—a series almost without a parallel in the annals of modern astronomy. But Mr Groombridge was not inclined to be satisfied with merely registering his observations, he applied himself with equal industry to the harassing labour of reduction, on which ten years more were exhausted; until, in 1827, he suffered a severe attack of paralysis, from which he never perfectly recovered During this period he had applied the reductions which depend upon refraction, as well as instrumental and clock errors, to *all the observations*, and had obtained the mean places of about one-third of the whole number, so that nothing more was required for obtaining the catalogue, precisely as it would have appeared from his own hands, except to apply the corrections for aberration, nutation, &c, according to his own tables"

Such is the sort of labour by which an unassisted individual performs work which will vie with that of a large and permanent observatory; but the amateur has another line of utility. All questions connected with stars or planets—except the apparently simple one of making such observations as shall aid the prediction of their future places with, if possible, increasing accuracy from year to year—belong to the private observer, at least until such time as Governments shall found observatories for purposes expressly *equatorial*, as it would be convenient to call them (See p 73) We shall devote some pages to a very short account of the various ways in which a person fond of looking at the heavens, provided with a moderately good telescope and micrometer, may make himself useful, even without mathematical knowledge

Let us take first the variations of the fixed stars in magnitude and colour. It is evident that the question, whether a fixed star revolve on an axis or not, can never be settled except by some variations of appearance presented by its different parts, as they come one after another under the eye of the observer, and also that a regular succession of repeated appearances in a star is a very strong presumption of the existence of a rotation round an axis. For instance, the star β Persei will to-day, at 8 P M, appear of the second magnitude, to-morrow, at midnight, it will be decidedly smaller, and in another day, it will nearly have recovered its first appearance This succession of changes can be observed repeatedly, time after time, and the inference is, that the said star revolves round an axis in 2 days, 20 hours, 48 minutes The only question is, how such pretensions to accuracy can be sustained, since it is most evident that no one can pretend to say, to a minute or an hour, when the star is most or least brilliant. This question is one of a large number which every thinking person must ask, when he hears that prediction and accomplishment differ from each other by such portions of time as the twentieth part of a second; and in this particular instance it happens that an answer can be given which will satisfy the most scrupulous. To take a very simple case, let us suppose the length of the year is to be determined, that is, the time elapsed between the sun being twice successively in the summer solstice Let it be supposed that any one single observer is liable to a mistake—say of five minutes—one way or the other, in determining the exact time when the sun is in the solstice, so that, by possibility, the observations of two successive solstices may give a year ten minutes too long or too short. But remember that the error possibly to be encountered is an absolute quantity, not connected with the time elapsed between two observations. Suppose then that the time of the sun's solstice is obtained in June 1830, and June 1831. The year thus obtained may be ten minutes too long or ten minutes too short. Let us suppose that we have already a rough notion of the length of the year—say exactly 365 days. Instead of observing the solstice of 1831, let us wait till that of 1832. Then being liable to an error of five minutes, one way or the other, at each extremity, the two years so estimated may be ten minutes too long or too short Consequently, the single year obtained by halving the period of two years cannot be more than five minutes too long or too short If we had waited till June 1833, and taken the third part of the whole period (possibly wrong by ten minutes) for the actual length of the year, the error of a single year could not have been more than the third part of ten minutes; and if a hundred years had been so taken, the error could not have been more than the hundredth part of ten minutes, and so on Thus the art of astronomical observation consists, in great part, in taking results obtained at times so far distant from each other, that the error of the two extremities shall be divided among a great number of the periods in question, instead of being borne by one only; and the correctness of modern astronomy is thus in some degree due to Hipparchus, who lived about a century and a half before Christ This constitutes the great difference between astronomy and all other sciences, pure or mixed—except perhaps geology, in a small degree If Euclid could be discovered to-morrow to be a forgery of twenty years' date, it would matter nothing, in any sense, however remote, to the truth of any one proposition in geometry. But establish the fact that Tycho Brahé wrote in 1700 instead of 1600, and several of the fundamental results of astronomy are thereby proved to be wrong, more or less.

The catalogue of variable stars, considered as well established by Sir J. Herschel*, in 1833, is as follows. A few resolute private observers would probably increase it considerably :—

Star's Name	Period of Revolution			Variation of Magnitude		Discoverers
	D	H.	M.			
β Persei . . .	2	20	48	2 to	4	Goodricke . . 1782 Palitzch . . 1783
δ Cephei . .	5	8	37	3½	5	Goodricke . . 1784
β Lyræ . . .	6	9	0	3	4½	Goodricke . 1784
η Antinoi . .	7	4	15	3½	4½	Pigott . . . 1784
α Herculis . . .	60	6	0	3	4	W. Herschel . 1796
χ Serpentis— R A. 15h 41m P D. 74° 15′	180	——		7?	0	Harding . . 1826
o Ceti . .	384	——		2	0	Fabricius . . 1596
χ Cygni .	396	21	0	6	11	Kirch . . . 1687
367 (Bode) Hydræ .	494	——		4	10	Maraldi . 1704
31 (Flamsteed) Cygni	18 years			6	0	Janson . . 1600
120 (Mayer) Leonis .	Many years.			7	0	Koch . . . 1782
κ Sagittarii . .	do	do		3	6	Halley . 1676
ψ Leonis . .	do	do.		6	0	Montanari . 1667

* The reader will find the *Treatise on Astronomy*, in the Cabinet Cyclopædia, the most instructive and correct in the English language, and for the history of astronomical

To these may be added the sudden appearance and disappearance of stars without any apparent cause, such as the star of Hipparchus, which led him to draw up the first catalogue on record, and that recorded by Tycho Brahé, in 1572. From the appearance of a new star, in the same part of the heavens, near Cassiopea, in the years* 945, 1264, and 1572, it seems possible that a few years after 1872 the same appearance may again be presented.

The disappearance of stars is a well-recorded fact, nor is the *lost Pleiad* of mythology the only instance. One cause of the loss of a star out of a catalogue has been this, that the supposed star was in fact a planet, which of course continued moving in its orbit, instead of remaining to be verified by those who afterwards examined the catalogue. In this way the planet Uranus appears once or twice in old catalogues as a star. And this considerably enhances the merit of Sir William Herschel, who, it must be observed, was not merely gazing through a telescope, without any object but to pick up chance curiosities, but was examining the whole visible heavens bit by bit, and time after time, that by successive investigations, *with the same telescope*, he might note any changes of magnitude, colour, or motion; and a very recent communication of Signor Cacciatore†, of Palermo, shows the use of continued investigation

discoveries, he may consult the Treatise in the Library of Useful Knowledge (History of Astronomy), or the Historical Account of the Progress of Astronomy, by Mr. Narrien. Baldwin, 1833. But we do not cite the treatise above-mentioned merely because it is a good treatise on astronomy, but because Sir J. Herschel is one of the first authorities on extra observatorial astronomy which exist at present.

* It must be observed, however, that both the first years are stated as having been those of comets by Lubinietski, on various authorities, and as this writer mentions the *star* of 1572, we do not know on what evidence the first two are founded. On looking into Tycho Brahé, *De Nova Stella*, p. 331, we find that the authority for the two first *stellæ* (we say this, because the Latin word may stand for star, planet, or comet) is his own contemporary, *Cyprian of Leovitia;* and of the star of 945 (or more probably 944) Tycho remarks, *sed a quo Historiographo id habeat, non adducit.* On the star of 1264 Tycho says, *Annotavit ille descriptionem ex quodam manuscripto codice desumsisse.* Now neither evidences will do at the present day, even to establish a comet, much less to distinguish a supposed new star from a comet, which other authorities tend to establish. Tycho Brahé himself seems to think, that if he does not doubt the evidence, others may; for he adds, *Nec facilè crediderim illum hæc falsa pro veris nobis obtrusisse. Quorsumne id faceret?*

† In a letter to Captain Smyth, R.N. Read to the Astronomical Society, Dec. 11, 1835.

"In the month of May I was observing the stars that have proper motion—a labour that has occupied me several years Near the 17th star, 12th hour, of Piazzi's catalogue, I saw another, also of the 7 8th magnitude, and noted the approximate distance between them. The weather not having permitted me to observe the two following nights, it was not till the third night that I saw it again, when it had advanced a good deal, having gone farther to the eastward, and towards the equator But clouds obliged me to trust to the following night. . When at last the weather permitted observations at the end of a fortnight, the star was already in the evening twilight, and all my attempts to recover it were fruitless—stars of that magnitude being no longer visible Meantime, the estimated movement in three days was 10″ in right ascension, and about a minute, or rather less, towards the north So slow a motion would make me suspect the situation to be beyond Uranus"

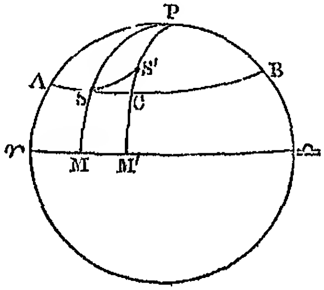
Here, then, is somewhat more than a suspicion of a new planetary body. It may be a century before it is recovered again, or it may have been found again at this moment. But it will always be easy to establish by calculation, as to any new planet, whether it was or was not the star observed, at the time and in the place specified, by the worthy successor of Piazzi.

Changes in the place of stars are well known, though not of so great magnitude as the one in the preceding paragraph When a star still appears to have motion, over and above that which is due to precession, nutation, and aberration, it is called a *proper motion,* or one really existing in the star. The three motions just cited, being common to all the stars, according to their different laws, have been traced to different motions of the earth But when one star appears to have other motion, which another close to it has not, it is then necessary to attribute the apparent motion of the first to a real motion in the star If we could discover a new motion, common to all the stars, and amounting to this, that all the stars in one part of the heaven increased their distance a little, while all those in the opposite part came nearer together, it would then be evident that the cause was a motion of the whole solar system towards the point at which the stars *opened* most Considering the solar system according to the laws of mechanics, which have been so successfully applied to the derivation of the *relative* motions of the sun and planets, it is millions to one against the sun being absolutely at rest in space But the questions—which way the whole system is moving together, with what velocity, and how soon we may expect to ascertain these points ?—are wholly unanswerable. All we know of the distance of any fixed star from us is negative—namely, that it is not less than about five thousand million of times the distance from the surface to the centre of the earth it may be this only, or near it, or it may be a hundred times as much, or even more. In the mean time, the proper motions of such stars as have them do not exhibit any such degree of relation as will justify our supposing that they arise from a motion of our system, as will more distinctly appear in the following list* of such stars as have more than half a second of motion, either in right ascension or declination The first column contains the name of the stars, if with a single number, it is Flamsteed's—if, with a number in parentheses, it is Piazzi's; or in brackets, Bradley's. A number of Hevelius has (Hev) The second column contains the magnitude of the star,—the third, the proper motion in right ascension, being the average of the yearly motion from 1800 to 1830, the sign —, denoting that the right ascension is diminished, while in all other cases it is increased. The fourth column contains the average yearly motion in declination for the same period, —denoting a southward motion, all the others being northward. The stars are arranged in the order of right ascension, so that it will be seen that the quantities and directions of the motions appear to be perfectly irregular, or *proper* to the individual stars, without any dependence on their places in the heavens The motions are expressed in hundredths of a second (of space), so that 59 means 59 hundredths of a second, or 59 per cent. of a second Observe, as to the quantity of the motion, that the sun's diameter contains about nineteen hundred seconds. In the columns which have been left vacant, no result has yet been obtained.

* Abridged from a paper by Mr. Baily, in the fifth volume of the Memoirs of the Royal Astronomical Society. A catalogue of proper motions, by M. Argelander, of Abo, has very recently been published, which, if requisite, we shall notice in the Appendix.

Star	Mag	R A	Dec	Star	Mag	R A	Dec
β Cassiopeæ .	2½	125		ζ *Ursæ Majoris* .	3	58	— 5
64 Piscium . .	6½	— 64		θ Centauri . .	2	— 84	— 98
(130) Ceti . . .	6	155		α Boötis . . .	1	—114	—199
(177) Ursæ Minoris	7	590		(127) Libræ . .	6½	60	
η *Cassiopeæ* .	4	218	— 50	χ Herculis . .	6	65	
(189) Piscium . .	6	84		γ Serpentis . .	3	7	—129
43 (Hev.) Cephei	5	206		49 Libræ . . .	5½	— 73	
(234) Ursæ Minoris	6½	245		ι Ursæ Minoris .	4	93	— 8
α *Ursæ Minoris* .	2½	146	0	A *Ophiuchi* . .	4½	— 69	—109
μ Cassiopeæ . .	5½	601		30 Scorpii . . .	7	— 83	
δ Cassiopeæ .	3	65	— 16	μ *Herculis* . .	4	— 23	— 72
τ Ceti . .	3½	—172	83	ρ *Ophiuchi* . .	4½	18	—106
(123) Ceti . . .	6½	154		(380) Draconis . .	5	77	
18 (Hev.) Persei	4	203	1	η Serpentis . .	4	— 55	— 73
12 Eridani . .	3½	15	63	36 Draconis . .	5	73	
(47) Eridani . .	4	253	52	χ Draconis . .	4½	59	— 37
ι Eridani . .	4	— 94	— 1	δ Ursæ Minoris	3	241	1
δ Eridani . .	3½	— 24	64	50 Draconis . .	5½	65	
40 *Eridani* . .	5	—214		b Aquilæ . .	5	83	
104 Tauri . . .	5	54		σ Draconis . .	5	184	
43 Camelopardali	5	— 67		α *Aquilæ* . .	1½	55	32
α Canis Majoris .	1	— 61	—124	(29) Sagittar . .	6	127	
α Canis Minoris .	1½	— 66	—112	69 Draconis . .	6	118	
β *Geminorum*	2	— 62	1	κ *Cephei* . . .	4½	147	9
11 Argûs . .	5½	78		η Cephei . .	3½	52	80
ρ² Cancri . .	6	— 52		76 Draconis . .	5½	112	
ι Ursæ Majoris .	3½	— 55	— 24	24 (Hev.) Cephei	5½	313	
π¹ Cancri . . .	6½	— 56		61 *Cygni* . . .	5½	546	310
θ Ursæ Majoris .	3	—140	— 53	77 Draconis . .	6	125	
υ Ursæ Majoris .	4½	— 73	10	70 Cygni . . .	6	91	
36 Ursæ Majoris .	5	— 65	— 7	τ Cephei . .	4½	82	14
ξ *Ursæ Majoris* .	4	— 32	— 56	ι Cephei . .	4½	93	5
83 *Leonis* . . .	8	— 69		28 Cephei . .	6	68	
β Virginis . .	3½	87	— 47	ρ Cephei . .	6	81	
4 (Hev.) Draconis	5	— 83		31 Cephei . .	5	59	
14 Virginis . .	6½	— 71		σ Pegasi . .	5½	63	
η Corvi . . .	4½	— 53	— 10	51 Pegasi . .	6	50	
8 Canum Ven. .	4½	—101	17	34 (Hev.) Cephei	5½	55	
γ *Virginis* . .	4	— 60	— 3	γ Piscium . .	4½	73	2
δ Virginis . .	3½	— 54	— 25	ο Cephei . .	7	105	
43 Comæ Ber. .	6	— 66		89 (Hev.) Cephei	6	398	
61 Virginis . .	4½	— 84	—101	85 Pegasi . .	6	117	

In the preceding list, the first thing which will strike the observer is, that the proper motions in right ascension are, on the whole, much greater than those in declination. But since right ascension and declination are the results of measurements, which depend only on the position of the earth's axis, and the plane of the ecliptic, or plane in which the earth moves round the sun, it cannot be supposed that there is any physical connexion between these circumstances and the motion of stars which appear totally unconnected with the earth. Such might be the surmise of any one, but it may be very soon shown that there is a simple geometrical reason why it must necessarily be, *ceteris paribus*, that the motions of stars are greater in right ascension than in declination.



Let P be the North Pole, ♈ M ♎ the equator, and S and S′ the places at the beginning and end of a year, of a star which has the proper motion S S′. Let A S C B be the circle of the apparent diurnal motion of the star at the beginning, and P S, P S′, the horary circles. Then the whole of the star's motion is S S′; the motion in declination is C S′: while the motion in right ascension is, *not* S C, but the part of the equator corresponding to S C, namely, M M′, greater than S C. If all the stars were in the equator, then the several S Cs (if we may invent such a plural) would coincide with their respective M M′s; and if there were all kinds of proper motions, we should upon the whole see no reason to call the variations of right ascension greater than those of declination. But if all the stars were very near the pole, very small proper motions would make differences of right ascension of several hours. To take the extreme case, suppose a star very near the pole to pass actually through the pole in the course of the year. Then there would be *twelve hours* difference between its right ascension on the two sides of the pole, and by supposing it to pass as near the pole as we please, we may thus make a yearly difference of right ascension as near as we please to twelve hours

The stars in the preceding list which have their names in Italics are *double* stars: that is, though appearing only single to the naked eye, they are separated by telescopes of more or less power, into two stars close to each other. There might easily be conceived one star which should hide another, owing to the line of their junction passing, when sufficiently lengthened towards us, through the earth's orbit, which in comparison of the distance of the stars from us is a mere point. But it would be against all probability to suppose that in an infinite extent of space so thinly spread with stars, in comparison with what might have been the case, a great number of hundreds of stars should thus appear couples, owing to the mere position of their lines of junction. If twenty thousand grains of sand were thrown up before the eyes of a spectator, at ten yards off him, and all deprived of further motion at one given moment, the chances are enormously against five hundred of them being so placed as to hide another five hundred in whole, or in part, and still more would be the probabilities against mere accident of position, as we must call it, making so large a proportion of discernible stars double. The inference to which the mind would be strongly led, is that this juxtaposition is a part of a real connexion between the two stars, which constitutes them one system having mutual relation between their motions, and very probably that which is found to exist between the sun and planets in our system. It needed no very long consideration of the planetary system (when it began to be known) to draw the inference that in all probability the fixed stars were themselves the suns of other systems, each controlling the motions of its own train of planets and satellites But experience has shown that this supposition lacked boldness, and was but a restriction instead of an extension No one was sufficiently hardy to imagine *two suns* demonstrated, and in some instances three or four strongly suspected, with all the probabilities of each having its own train of planets remaining just as before But we must explain what we mean by two *suns*.

The suns of a system must be defined to be those bodies which shine by their own light, and which are masses of matter comparable to each other in size, so that neither must be considered as a mere speck, when the other is likened to an orange.* This definition may require extension from future discoveries, to make it include all bodies to which it shall or may be convenient to give the name of suns, but at present it answers every purpose. If we could suppose Jupiter to have light of its own, just enough to be seen with the most powerful telescopes from a fixed star, or if we could suppose its reflected light to produce such a phenomenon, then the observers in that star would see our sun and Jupiter, as a bright star accompanied by another, extremely faint, which revolves round it, the two being inseparable by the naked eye. But as it stands, we have in our heavens stars of not very different degrees of brilliancy, and of which there is no reason for supposing that either is the only source of illumination to the other, but the contrary, since their lights are generally of nearly the same intensity,

* We are quite serious in saying that the following extract from Sir J. Herschel's Astronomy, (Cab Cycl.) contains a better view of the solar system than a great many volumes which preceded, with their clap traps of millions of millions of miles. See the Work, p. 287.

'Choose any well-levelled field or bowling-green. On it place a globe, two feet in diameter, this will represent the sun Mercury will be represented by a grain of mustard seed, on the circumference of a circle 164 feet in diameter for its orbit, Venus, a pea on a circle 284 feet in diameter, the Earth also a pea, on a circle of 430 feet; Mars, a rather large pin's head, on a circle of 654 feet; Juno, Ceres, Vesta, and Pallas, grains of sand, in orbits of from 1000 to 1200 feet, Jupiter, a moderate-sized orange, in a circle nearly half a mile across; Saturn, a small orange, on a circle of four fifths of a mile; and Uranus, a full-sized cherry, or small plum, upon the circumference of a circle more than a mile and a half in diameter. As to getting correct notions on this subject by drawing circles on paper, or still worse, from those very childish toys called orreries, it is out of the question To imitate the motions of the planets, in the above-mentioned orbits, Mercury must describe *its own diameter* in 41 seconds, Venus in 4 minutes 14 seconds, the Earth in 7 minutes, Mars in 4 minutes 48 seconds; Jupiter in 2 hours 56 minutes, Saturn in 3 hours 13 minutes, and Uranus in 2 hours 16 minutes.' To complete the above, we must add, that the model of the nearest fixed star must be at least 6000 miles distant from the bowling green.

and of different colours (though this is not conclusive). These stars revolve round each other, *in ellipses*, like the planets. But before proceeding farther, we have some remarks to make on the manner in which this subject concerns several, perhaps many, of our readers. The first motion mentioned, namely, the proper motion in the heavens, concerns the observatory astronomer entirely, both as to the phenomenon in question and the difficulty of detecting it. For not only is it his office to assign by prediction everything that affects the stars considered as reference points in the heavens, but the quantity in question is so small, that nothing but the most powerful instrumental aids and the greatest skill in observation will detect it. But the means of many private observers might be made useful in the delicate task of detecting the relative motions of double stars, nor need any one be deterred by the idea that he cannot himself make use of his observations after they are made, or apply them to determine what are called the *elements of the orbit*. There are several steps in astronomical work: firstly, the determination and selection of the phenomenon to be observed, and of the proper instrument, the investigation of the defects which are peculiar to that instrument, (and every one has its own,) and of the proper method of making the observation, so as to avoid as much as possible of the error, and have the means of removing the rest by subsequent computations, secondly, the observation itself; thirdly, the *reduction* of the observations, or the clearing them from the effects of one phenomenon and another, which must not be taken into account, fourthly, the discovery and selection of such methods and formulæ as will, when applied to the observations, produce those general *data* which are called *elements*, and when known, form the most convenient quantities with which to set out in the attempt to predict the future from the past; fifthly, the actual deduction of the future phenomenon. The first is the work of a mathematician and mechanician; the second, of any person who will give a short time to the practice of the rules and maxims deduced by the first, with or without understanding the principles on which they have proceeded. the third, of a very ordinary computer; the fourth, of a mathematician and natural philosopher—neither Newton nor Laplace was more than equal to his task in this department of the science; the fifth, of a skilful computer, well versed in the results of the fourth We need not enlarge on the advantages which would result, have resulted, and do result, from the same person being competent to every part of the preceding duty. what we have here to say is, that the desire of being useful may be accomplished in any one of the preceding paths, without much attention to the others. But our business is here with the actual observer, who has what is to most minds the most pleasant and easy task of the whole, though as indispensable to the success of the united operation as any other Indeed it is impossible to say which of the preceding should be dispensed with first.

A person with a moderately good instrument, and some attention to its use, will not find the results he may produce neglected. His fellow-labourers will take the raw material he furnishes, and apply all the successive steps of the manufacture to it. Nor will he lose the credit which is due to him, for to omit mentioning the name of an observer, the nature of his instrument, and the place where the original observations are to be found, would be to ensure the rejection of the results of such observations both abroad and at home The particular case in question, namely, the fundamental observations of double stars, are peculiarly pointed out as the most certain field of the private observer, *because they require no clock,* unless one be used as a convenient method of moving an equatorial telescope. The day of observation is all that is necessary to be known; and a time-piece, with its necessary accompaniment, a transit instrument, is not wanted An equatorial telescope of sufficient power to separate the two stars, and a *wire micrometer*, are the necessary apparatus. of the principle of the latter we shall give a general description, not entering into any of the niceties of its construction, and supposing throughout that the instrument is perfect.

The wire micrometer consists in the addition of an apparatus to the eye-glass of a telescope, such that, on being inserted into the tube, the field presents the usual appearance of a luminous circle, cut by four very fine wires, parallel, two and two, the first pair being at right angles to the second. It is found that the apparatus can be turned round, so as to place either pair of wires in any direction.

One pair of wires is fixed, but the other pair consists of one fixed and one movable wire; the latter always remaining parallel to the fixed wire, but capable of having its distance increased or diminished by a screw, which carries round a small circle graduated on the edge, into (say) 100 parts. The threads of the screw are so small, that a whole revolution of the graduated circle carries the thread to or from its parallel thread by a very small space, and as we have supposed 100 divisions on the circle, and as the graduations of this latter are so distant that the position of a fixed index may be read on the circle within a quarter of a division, we have thus the four-hundredth part of the effect of a whole revolution easily ascertainable We might suppose the other wire moved by a screw at the other end, but this is not necessary. We can now easily see that one wire may be made to cover one star, (which is very easily continued if the instrument be carried by clock work* at the same rate as the heavens,) and the movable wire may then be adjusted to cover another star, both being in the field together The observation is then made, and is to be read off. See how many revolutions, and parts of revolutions will bring the movable wire home to the fixed wire. the distance of the two stars is then known in terms of the divisions of the micrometer

The question now is, what do the divisions of the micrometer stand for? If the artist attempted to construct the instrument so that each revolution of the screw should answer exactly, say to 20 seconds of distance, he would certainly lose his labour. Screw-cutting is in a very high state of perfection, all things considered, but the errors of the screw are, of course, magnified in the telescope, perhaps 250 times. The artist can cut the divisions of the screw sufficiently near to equality *with each other*, but cannot determine with sufficient nearness how many seconds of space in a given telescope will answer to each revolution. The observer, therefore, being only furnished with an instrument, each division of which means *something*, must find out from the heavens what that

* An equatorial telescope is an awkward instrument if the hands must be continually employed in keeping the star in the field. Clock-work is now made at a cheap rate, when compared with the price of a good telescope.

something is And this notion of an astronomical instrument, so different from the common one, namely, that it is an awkward mass of wood, glass, &c., which must be taught by one star what to say of another, will be here easily illustrated. The fundamental unit of measurement throughout astronomy is the diurnal revolution, which is made to be 24 hours If a star be exactly in the equator, every second of this 24 hours (page 27) answers to 15 seconds of *space*. The observer separates the wires by (say) exactly 10 revolutions of the screw, and putting the telescope upon a star in the equator, (if not, a correction must be applied, which is not here to be considered,) he finds that the star takes 22½ seconds by a sidereal clock to move from one wire to the other, or 22·5, answering to 15 times as many seconds of space, or to 337″·5 The tenth part of this, or 33″·75, is the value of each revolution of the screw, and the hundredth part of this, or 0″·3375, is the value of each of the hundred graduations A common clock or watch will here be sufficient, but even without this, he may measure the diameter of the sun on the meridian, at which time the diameter in question is given in the Nautical Almanac (predicted) Suppose, for instance, he finds it to be 60 revolutions, and 12 of the divisions of a revolution, or 6012 divisions; and that the Nautical Almanac gives 31′ 56″ for the diameter of the sun, or 1916″. Then 1916, divided by 6012, gives 0″·3186 for each division, or 31″·86 for each revolution.

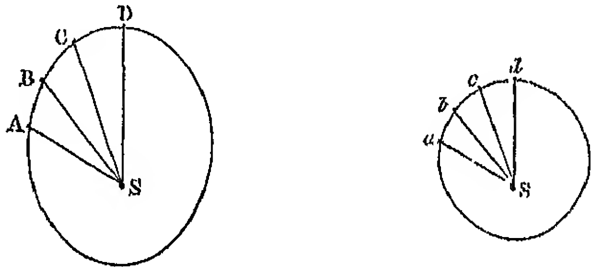
By such a rough description, it may be imagined that an individual with leisure to follow his own views, some means of providing instruments, and a moderate zeal for the prosecution of details, need not be deterred by any idea of difficulty from endeavouring to be of use in practical astronomy. We now proceed with the subject of double stars.

It was observed by Sir W Herschel that some of these double stars revolved slowly round each other, by measuring what is called their angle of position, that is, the angle made with the meridian, by the line joining the stars, which, were there no rotation, ought to remain always the same. In 1803, Sir W Herschel announced to the Royal Society the motions of γ Leonis, ε Bootis, ζ Herculis, δ Serpentis, and γ Virginis, all of which have been subsequently confirmed. Many hundreds of stars have since been added to the list; every accession of power to the telescope separates new single stars into double stars, and there is no denying the possibility of every star in the heavens being double, though it is a strong circumstance in favour of single stars, that our own sun appears to be one. Forcible as are the presumptions that every double star is a connected system, and not a result of the position of the line of junction, it is yet proper to distinguish between stars which are proved to be connected, and those which are not (as yet). The latter are therefore simply called *double* stars, and the former *binary* stars, or more properly *binary* systems. It is found by observation that certain double stars revolve round each other, and it was naturally the first inquiry, whether they revolved round each other according to the same laws as our planets round the sun, or satellites round their primaries. The method of testing any astronomical theory, is to assume it, and deduce its consequences, and then to see whether those consequences are written in the heavens. This method is completely misunderstood by almost all the various speculators who have tried to overthrow the Newtonian system. They seem to imagine for the most part that Newton reasoned as follows: if such and such attractive forces exist, certain motions must ensue; but those specified motions are found to exist, therefore the attractions laid down must exist also. This would not be good reasoning; for the only deducible result is, that there is a consequent probability in favour of attraction. The real state of the case is contained in the following *demonstrated* propositions. 1. That bodies on the earth are pulled towards the earth by a force to which the name of attraction is given; 2. That this does not depend upon the air, since it holds of bodies in an exhausted receiver; 3. That detached portions of matter attract each other on the earth[*]; 4. That all the motions of the solar system do take place just as, it can be shown, they would take place if all matter attracted all other matter according to the Newtonian law. All these propositions are demonstrable and demonstrated: it is a question for the mind of the reader, how far it is likely that the

[*] Proved by Maskelyne's and Cavendish's experiment. See PENNY CYCL., article ATTRACTION.

first three should be true, and the last also from any other cause *except attraction*

To carry this inquiry as far as the fixed stars, it is necessary that the consequences of the Newtonian law should be deduced and compared with observation. The only difficulty is one which the mathematician does not feel, but which must strike a reader with some force who reflects on these things with an elementary knowledge of mathematics. All the celestial spaces are to us nothing but projections on a sphere in the manner described in p. 3 Thus the distance between two stars does not depend upon their real distance only, but also upon the degree of obliquity under which that distance is seen: and if one star revolve round another, it is very obvious that we do not see the real orbit, but the projection of the real orbit upon the sphere. Now this appears at first sight to be only the change of one orbit into another. what we want to make apparent is, that it will be a change into an orbit described according to laws quite different from those observed in the solar system, so that if the *foreshortening* of the real orbit were neglected, it might be inferred that the theory of mutual attraction does not hold of binary systems as a sufficient explanation of observed phenomena.



Let S be one of the stars, and let A B C D be the real orbit in which the other moves relatively to it, but let its obliquity to the sphere be such, that it is foreshortened into *a b c d*. Supposing the orbit to be an ellipse of which S is the focus, it follows as a necessary consequence of S constantly attracting the other star, that equal areas must be described in equal times; that if A B C D be the positions of the second star relatively to the first, at any equal intervals of time, then A S B, B S C, and C S D must be areas

equal extent Now this proposition is practically true for the
)jected orbit, owing to the angle under which it is seen being so
all, that any line drawn to a point in it from the earth may be
isidered as at right angles to its plane, so that the projection is
truth orthographic, as described in page 52 And it is a pro-
ity of the orthographic projection, that areas equal to each other,
ing parts of the same plane, are projected into other areas differ-
; from the first, but still *equal to each other*. Consequently,
ual areas appear to be described in equal times in the projected
)it, which, therefore, in this particular feature, presents no mark
distinction from the real one

Again, the projected orbit is an ellipse, as well as the real orbit
)w then, having ascertained the *apparent* orbit, are we to know
iether it is not the *real* orbit? How can we proceed to determine
e real truth of the probable fact, that the orbits of double stars
e not all so arranged that the eye views them without any obli-
ity? The truth is, that though the apparent orbits are ellipses,
d described so that equal areas are passed over in equal times,
*t the point about which equal areas are described in equal times is
t the focus of the ellipse.* This is the effect of the projection or
'eshortening, and so far as alteration of Kepler's laws is in ques-
in, the only effect Consequently, it must be ascertained in what
sition, if any, an actual orbit can be placed, which being itself so
sited as to be among the possible originals of the apparent orbit,
ty have the star in its focus which has been considered as the
imary This difficulty, which is a purely mathematical one, is
troduced and overcome, the result is, that orbits are found obey-
g in every respect the laws of Kepler and therefore assimilating
e relative motions of binary systems to those of our sun and
anets, and agreeing better with the observations than the obser-
tions agree with each other. For it must be observed that the
easurement of the angles of position, or angles made by the line
junction of the stars with the meridian, is a very rough and in-
act kind of observation, and a difference of five or six degrees
ll sometimes be found in the individual measures out of suc-
ssive sets taken nearly at the same time But when the angles
position, as they should be if the deduced orbit were perfectly

correct, are compared with those which actually have been observed the differences are found to be mostly under one degree, and very seldom above two The methods by which a mass of conflicting observations, made discrepant by instrumental and personal errors, have been thus made to give conglomerate results according with Kepler's laws to a greater degree than could fairly have been expected from the appearance of the observations themselves, are due to Sir J Herschel, who, in a paper published in the fifth volume of the *Mem Astron Soc*, has deduced from his own observations and those of others*, the elements of the orbits of γ Virginis, Castor, σ Coronæ, ξ Ursæ Majoris, and 70 Ophiuchi, and in a subsequent paper, in the sixth volume, ξ Boötis, and η Coronæ are added, with a new determination of γ Virginis. There can be nothing connected with astronomy of more interest to a general reader, than to see the various steps by which a process is passing through its rough stages, before an uninteresting degree of accuracy is attained. Nobody but a mathematician can sympathize with the director of an observatory, using all his efforts of body and mind, so to improve the lunar theory as to abolish the second of time (or thereabouts) by which she will not † come on the meridian according to prediction But a second in the lunar theory, answers to five years in that of γ Virginis, belonging to a department in which from the nature of the case observations are so rough, that instead of cal-

* The observers who have forwarded this, the most interesting addition to the phenomena of astronomy since the time of Galileo, are (in alphabetical order, and the living with their titles) Professor Amici, M. Bessel, Bradley, Rev. W. R. Dawes, W Herschel, Sir J. Herschel, Maskelyne, Mayer, Pound, Captain Smyth, R N, Sir J. South, Professor Struve.

† The following supposed dialogue between two astronomers is not exaggerated —

A. Have you seen the ——— volume of observations for this year?

B No, but I am told the moon is very much out.

A Yes, indeed, almost two seconds in one place.

B The small planets altogether wrong, as usual, I suppose?

A. Yes. Pallas is out nineteen seconds!—however, some of that is in the epoch.

B I wonder whether we shall ever know anything at all about those small planets, &c?

This will serve the reader to adjust his notions, when he hears, in one point of view, that modern astronomy is very correct, and in another that it is all wrong. The first looks to what has been obtained; the second to what remains to be done.

culating different portions of the area of an ellipse, it is as much as the data are worth to cut out parts of a paper ellipse, and compare their weights. The following approximations (first and second already alluded to) will show the state of this class of observations The second is derived from the addition of a large number of new observations, and exhibits that degree of similarity which at once proves that much has been done, and much remains to do

Orbit of γ Virginis.

	First Result	Second Result.
Major Semiaxis . .	11″·830	12″·090
Eccentricity . .	88717	8335
Perihelion projected . .	17° 51′	36° 40′
Perihelion from node on the orbit .	not given	282° 21′
Inclination to plane of the heaven .	67° 59′	67° 2′
Node	87° 50′	97° 23′
Period in tropical years .	513·28	628·90
Mean annual motion . .	—0°·70137	—0°·57242
Perihelion passage, A. D. .	1834·01	1834·63

Of the stars mentioned in the preceding list, the approximate elements of the *real* orbits are as follow.—

Star.	Revolution in years.	Major Semiaxis	Eccentricity.	Inclination to the projected orbit
γ Virginis .	629	12″·090	8335	67° 2′
Castor .	253	8″·086	·7582	70° 3′
σ Coronæ .	287	3″·679	·6113	41° 15′
ξ Ursæ Maj. .	61	3″·278	·3777	56° 6′
70 Ophiuchi .	80	4″·392	·4667	48° 5′
ξ Bootis .	117	12″·560	·5937	80° 5′
η Coronæ .	44¼	0″·8325	·2603	37° 24′

ζ Cancri is suspected to revolve in an orbit nearly circular, in about fifty-five years. Sir J. Herschel has remarked, with considerable probability, that these orbits seem rather *cometary* than planetary, that is elongated, not nearly circular, oval forms. The last star, η Coronæ, is the principal triumph of Sir W. Herschel's prediction. It has actually completed upwards of a revolution since it was first observed; and the greatest distance of the two stars falls below what was once supposed would ever be matter of observation.

It must be observed that either star may be taken as fixed: the relative orbit of each round the other being the same for both. Some double stars have, at the same time, proper motion common to both, (which is another proof of connexion,) and thus exhibit the phenomenon of a system in a state of translation through space, which we must, more or less, believe to be the case in our own. Though it may not be directly in our way, we shall take notice of a very remarkable addition, which our present knowledge of the motions of double stars makes to an argument of ancient standing. The practice of making some resemblances the grounds of suspecting others, is as old as any attempt to reason, and is justifiable to a certain extent, depending upon the number of resemblances which have been observed. The sun is a mass of matter which gives light; so far it resembles the stars. But of the sun we know further, that its light and heat are essential to the preservation of an immense organized system, which could not exist without them. The inference has then been drawn, not without probability, that the stars are of the same service to other systems. On the other hand, there have been those who find the use of the stars as subservient to the wants of men, and whose minds do not feel any necessity for further supposition as to the use of their existence. To them it must at least be conceded that their argument is to the point: and that if it be impossible to disbelieve, consistently with all our terrestrial experience, in the utility for some purpose or other of all that exists, it is incumbent on us, on the other hand, to admit a degree of utility in navigation and geography to the fixed stars, which may justify those who can do so, in refraining from further attempts to create uses from their own imaginations. Nor does it in the least touch this argument that the stars are not all useful, for the same applies to all the products of the earth which have not yet been obtained, to most of the minerals of India for instance; or that the advantages of them are in many instances of comparatively late discovery, for this applies equally to iron considered as the material of a rail-road. But the knowledge which has been lately added to our stock on the subject of double stars, presents an entirely new method of viewing the subject. In our own system we see that the laws under which the planets revolve round the sun are conducive to the maintenance of their existence, and something of the manner in which this is effected. If the motion of the earth were stopped, nothing would hinder its falling into the sun with a shock which would disorganize the whole, even supposing that life and vegetation could exist up to that moment, under the continually increasing heat and light Now in the relative motions of the double stars, we see the same method of preventing a mutual shock,—for what purpose?—for our geography or navigation? This is excessively difficult to be supposed of double stars, which are less than a second of apparent diameter apart The argument in favour of organization in the celestial bodies is very much increased in probability by the discovery of a species of relation which makes a direct provision that, under actually existing laws, one shall not become dangerous to the maintenance of the state of another

Among the phenomena which have been observed of binary systems or double stars, one of the most remarkable is their difference of colour, the colour of one being usually near one end of the prismatic spectrum, and that of the second from the other, the larger being most frequently nearer to the red, and the smaller to the violet. There is an infinite number of varieties of colour among the heavenly bodies; but so far as can be ascertained, there is no distinction between the optical properties of the light of one star and of another, except that which also belongs to the same differences of colour in terrestrial objects.

We shall finish by some notice of the *nebulæ* or *nebulous* bodies, as they are called The first and great nebula of our heaven is the milky way, extending all round the sphere in the manner pointed out in the maps. Of this phenomenon it is to be remarked, that the nearer we turn our eyes to it, the more do the smaller stars multiply and crowd together. And the milky way is found by powerful telescopes to be itself an enormous collection of minute stars, each yielding too little light to be separately visible, but conveying altogether the faint impression from which the name is derived The inference drawn is, that we are situated in an immense stratum of stars, the length and breadth of which is very many times greater than its thickness, so that when we look through the thin part, we see stars in sufficient number, but when we look *along* the stratum, we see smaller and smaller stars, more thickly placed than before, and terminating in those which are so distant that their united effect is that of a mere cloud This was the opinion, or if it be considered as perfectly established, the discovery, of Sir William Herschel, and it opens a wide field of reasonable speculation For besides the milky way, the heavens are found to be covered with minute patches of light, more or less thickly scattered in every part These differ from stars in being of finite magnitude; some of them are visible to the naked eye on clear nights. Some, in a telescope, are found to consist of clusters of stars, in some, the uniformity of appearance under a low power is changed by a higher into that of a varied scene of lights of different degrees of intensity. The presumption is, that every such nebula is a *partial universe* of itself that is, composed of a number of stars so great and so distant from *our cluster*, that the latter would appear from any nebula in some such form as the nebula appears to us. This is, of course, a mere presumption, similar to those which have been already noticed; but it possesses a degree of probability with which no other hypothesis can compete at present The number of forms which nebulæ assume, and the various appearances which they present in the telescope, it is out of the question to attempt describing. The writings of Sir W. and Sir J. Herschel contain almost all that is known on the subject. The catalogue of the latter, printed in the *Phil Trans* for 1833, contains a list of 2306 such objects visible at Slough: and his journey to the Cape of Good Hope is understood to have for one principal object the extension of this list to all the nebulæ in the lower part of the southern hemisphere. On this subject* "he is somewhat surprised at the extraordinary paucity of close double stars, which cannot arise from want of power in the telescope, or from the nature of the climate for he considers his mirrors as perfect as it is possible to make them; and he represents the beauty and tranquillity of the climate to be such that the stars are reduced to all but mathematical points, and

* *Ast. Soc.* Monthly Notice, Dec., 1835.

allow of their being viewed like objects under a microscope But although the number of double stars is so small, considering the richness of the southern heavens in stars, yet he represents the nebulæ as very copious, and has accordingly collected a numerous list, &c"

Nobody can well describe nebulæ who is not in the habit of seeing them; and for this reason we recommend the work on astronomy already cited, independently of other merits. The following descriptions of a few objects are taken from the list of nebulæ mentioned above (*Phil Trans* 1833) In interest they will be worth more than any abstract —

No 1622. R A. $13^h\ 22^m\ 39^s$ N.P.D 41° 56′

"This very singular object is thus described by Messier —'Nébu-"'leuse sans étoiles' 'On ne peut la voir que difficilement avec "'une lunette ordinaire de 3½ pieds Elle est double, ayant cha-"'cune un centre brillant éloigné l'un de l'autre de 4′ 35″ Les "'deux atmosphères se touchent' By this description it is evident "that the peculiar phenomena of the nebulous ring which encircles "the central nucleus had escaped his observation, as might have "been expected from the inferior light of his telescopes. My father "describes it in his observations of Messier's nebulæ, (which are not "included in his catalogues,) as a bright round nebula, surrounded "with a halo or glory at a distance from it, and accompanied by a "companion, but I do not find that the partial subdivision of the "ring into two branches throughout its south following limb was "noticed by him. This is, however, one of its most remarkable and "interesting features. Supposing it to consist of stars, the appear-"ance it would present to a spectator placed on a planet attendant "on one of them, excentrically situated towards the north preceding "quarter of the central mass, would be exactly similar to that of our "milky way, traversing in a manner precisely analogous the firma-"ment of large stars, into which the central cluster would be seen "projected, and (owing to its greater distance) appearing, like it, to "consist of stars much smaller than those in other parts of the hea-"vens. Can it then be that we have here a real brother system, "bearing a real physical resemblance and strong analogy of structure "to our own?—The elliptic form of the inner subdivided portion "indicates with extreme probability an elevation of that portion above "the plane of the rest, so that the real form must be that of a ring "split through half its circumference, and having the split portions "set asunder at about an angle of 45° each to the plane of the other."

No. 2060 R A $19^h\ 52^m\ 12^s$ N P D 67° 44′

"In my father's observations the true form, (like that of a double-" headed shot or dumb-bell,) was of course distinctly perceived, and "the small stars it contains are noticed, and taken as an indication "of its resolvibility I incline, however, to the opinion of their being "accidental stars; (of which multitudes exist in the surrounding re-"gion). But here, as in the former object, the feature which gives a "peculiar interest to the whole nebula, and alters entirely the light in "which its physical constitution must be considered, has been hitherto "overlooked,—I mean the faint nebulosity which fills in the lateral "concavities of the body, and converts them, in fact, into protuber-"ances, so as to render the general outline of the whole nebula a "regular ellipse, having for its shorter axis the common axis of the "two bright masses of which the body consists, that is to say, the "*longer* axis of the oval form under which it was imperfectly seen "by Messier"

No 218 R A $2^h\ 11^m\ 58^s$ N P D. 48° 25′

"An extraordinary object It is of the last degree of faintness, "and may very well be unperceived though full in the field of view. "There can hardly be a doubt of its being a thin flat ring, of enor-"mous dimensions, seen very obliquely."

The observations of nebulæ must be principally interesting on account of the slow changes which appear to be taking place in them. But to the private observer they must be considered, in conjunction with double stars, as affording a valuable means of trying the power of his telescope, and the state of the weather for observing. They may be ranged in classes according to the difficulty of perceiving them, and thus the possessor of a telescope may determine the rank his instrument is entitled to hold. For the very different accounts given by observers of the performance of object-glasses, when compared with their stated dimensions, and such other circumstances as to all appearance should give superiority or inferiority, must lead us to conclude that each such glass is an instrument by itself, not, altogether at least, to be considered as one of a class. Such a list, under the title of "A List of Test Objects," was communicated by Sir J Herschel to the Astronomical Society, and is published in the eighth volume of their memoirs. By permission of the Council of that Society, it is republished at the end of this treatise The references to the catalogues, &c., which serve as the names of the stars, hardly need explanation, since by the approximate right ascensions and north polar distances, the places of the several objects may be found in the maps (Σ, Struve; H, W. Herschel; h, J Herschel)

We shall finish the chapter with an account of the selection of objects which have been made in the maps

The stars in Piazzi's, Bradley's, and Lacaille's catalogues have been chosen, and all those of Flamsteed (Mr. Baily's edition) are included

Piazzi's catalogue, published in 1814, contains 7646 stars, all which are inserted in the maps.

Bradley's stars are taken from the catalogue in Bessel's *Fundamenta Astronomiæ*, published in 1818 (the only place in which the results of Bradley's Astronomy exist in a reduced form: see PENNY CYCLOPÆDIA, article BRADLEY)

There are 3222 stars in this catalogue, of which only 216 are not in Piazzi, all these are inserted in the maps, but are without a reference. Lacaille's *Cœlum Australe Stelliferum* was published in 1763, it contains observations of 10,035 stars, of which 1942 are formed into a reduced catalogue, all of which are in the maps.

Piazzi's and Bradley's stars were reduced to the epoch, 1840, by the quantities given in each catalogue, but those of Lacaille were brought up graphically, by moving them, in longitude only, on the maps.

Lacaille is the authority for the southern hemisphere; but since the time when these maps were constructed, a catalogue of 606 southern stars has been printed by the East India Company, deduced by Lieutenant Johnson*, late of the St. Helena Artillery,

* This catalogue obtained the gold medal of the Astronomical Society, and though the instruments employed were not of the very first description, it was asserted by the committee appointed to examine it, to be capable of vying with those which have issued from the first-rate observatories of Europe.

from his observations while in charge of the observatory in that island The difference between the stars' places as given by Lieutenant Johnson and by Lacaille, is not sufficient to be visible in the maps, but the following new stars, which appear to have been observed by the former only*, are here given, with their numbers in the new catalogue, their magnitudes, right ascensions and declinations for the year 1830:—

Number in Johnson's Catalogue, and name of constellation		Mag.	R A 1830			Dec. 1830 South		
5	Octans	6½	0h	15m	—s	89°	18′	32″·0
327	Octans	7	14	13	33,60	87	25	35·9
388	Octans	6½	15	59	39,70	86	0	4·7
395	Norma	5	16	6	—	49	38	1 1
423	Octans	6	16	55	6,76	89	14	59 4
433	Octans	6	17	14	54,90	87	37	12 8
496	Octans	7	19	26	16,40	89	34	0 8
549	Octans	6	21	56	10,00	86	49	8 8
553	Grus	5	22	5	—	42	11	1 8
578	Octans	6	22	57	40,30	88	24	38·2

Flamsteed's number has always been preferred, where it exists, and appears in large print; Lacaille's number has one line; and that of Hevelius has two lines drawn under it; that of Piazzi, where it is the distinction of the star, is in small Italic numerals All Mr. Baily's corrections in his valuable edition of Flamsteed's Catalogue, recently published, have been attended to as to Bayer's letters and Flamsteed's numerals. The former were arranged by Bayer, so that the order of the letters might also be that of the magnitudes of the stars; the latter were attached to the stars in order of right ascension The stars marked double are taken from Sir W. Herschel's Papers in the Philosophical Transactions for 1782 and 1785, and from Struve's Large Catalogue, the Dorpat Catalogue, as it is frequently termed, published in 1827. Piazzi has separated many of the double stars, and given the positions of both. Where the scale will allow, the two stars are laid down, and Piazzi's numbers given. All Sir W. Herschel's Nebulæ (which include

* They do not appear in the Astronomical Society's Catalogue, nor in Lacaille.

Messier's,) are laid down with the numbers and classes affixed, namely, 1000 from *Phil Trans* 1786; 1000 from *do do* 1789, and 500 from *do do* 1802; 500 are added from Sir J. Herschel's Catalogue already quoted; and 629 in the southern hemisphere are taken from Mr. Dunlop's Paper in the Philosophical Transactions for 1828. From the latter source the *Nubecula major* and *minor* are laid down. Sir W. Herschel's nebulæ have numbers and classes (for instances, 23 VIII); those of Sir J Herschel have no classes, but have the larger numbering; while those of Mr Dunlop are in small print.

All these stars, as before stated, are reduced to the year 1840, that is, are in the position in which they will be in the year 1840. To form a notion of the way in which precession will appear to carry a star, look at the nearest parallel of latitude, and imagine the star to move parallel to it, in the order of the signs, at the rate of a degree in seventy-two years. The position of the parallel of latitude will enable the reader to estimate whether the motion is greatest in right ascension or in declination.

The stars which have proper motion are denoted by an arrow annexed, which points out the direction of the motion, and gives a notion whether it is great or small. To gain a better idea, look at some of the stars in the preceding list (page 89).

APPENDIX*.

VITHIN the last few years, the examination and measurement of ouble stars has been prosecuted with great activity. We propose o give a slight sketch of the methods hitherto most successfully dopted in measuring double stars†, both on account of the intrinsic alue of this branch of astronomical inquiry, and because it is not ncluded in many of the ordinary treatises, though peculiarly within he reach of private observers. The measurement of a double tar is the determination of the position of one of the stars with egard to the other, (assuming the larger as a fixed point,) so as to e able to distinguish and define any change of position between hem At first this was done by noting the differences of right asension and declination as the stars passed over the meridian . but ne difficulty of observing the difference of right ascension made his (in most cases) an exceedingly inaccurate method. Sir W. Herschel introduced another and much more accurate mode of observation. Placing a wire in the focus of his eye-piece, he turned ne eye-piece round until the wire was parallel to the line passing hrough the centres of the two stars, when they might be threaded s it were in the same moment. Hence, the position of the same ine when perpendicular to the meridian being known‡, the angle etween the two positions of the wire, which gives the angle which ne line joining the stars makes with the parallel of daily motion, vas also known This is Sir William's *angle of position*, and by ne further distinction of *preceding* or *following*, *north* or *south*, he xed the situation of the smaller star with respect to the larger vithout ambiguity The *distance* between the stars was at first

* For this Appendix the author is indebted to his friend the Rev. R Sheepshanks.

† The observation of *nebulæ* requires so much light, that only telescopes of the argest aperture can be usefully employed in the pursuit. It is to the two Herschels hat science is indebted for almost every thing which is positively and correctly known n this department of astronomy, which, with the researches as to double stars, may e called the *Herschelian* branch of Astronomy.

‡ Simply by turning the eye-piece until one of the stars runs along the wire.

estimated in diameters and parts of the larger stars, but afterwards a very ingenious apparatus was used, in which two small moveable lamps were made to subtend in one of the observer's eyes the same angle which the magnified stars did in the other. The distance of the lamps from each other, and from the observer, together with the magnifying power of the telescope, supply sufficient data for determining the distance between the stars. With such imperfect, or rather with such inconvenient means, (for the results are wonderfully accurate,) Sir W. Herschel formed his catalogues of double stars, and by a comparison between the measures of the same stars (especially of the angles of position) made at considerable intervals, ascertained the fact that double stars are in many instances a connected system.

The discoveries and measurements of Sir W. Herschel were made wholly with reflecting telescopes, mounted so as to move with freedom vertically and sometimes horizontally; subsequent observers have for the most part employed refractors mounted equatorially*, and the position wire micrometer. When the telescope of an equatorial is pointed on a star, one motion, *viz.*, that of the whole instrument round its axis, with a velocity equal to the apparent motion of the heavens, will keep the star perpetually in the field of view. This motion may be given by one hand turning a handle with a Hook's joint, which works the tangent screw of the hour circle, or still better, by clock-work. The position micrometer, in its newest and best construction, is of this form:—

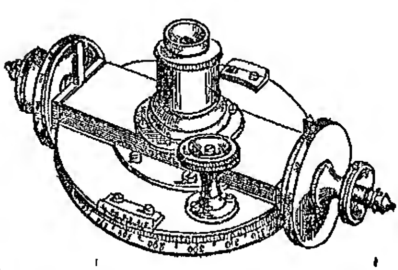
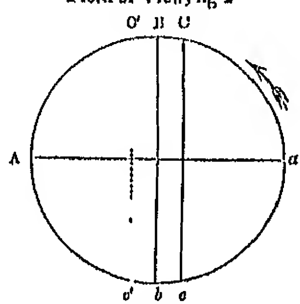


Fig. 1. Position Wire Micrometer.



Field of View, fig. 2.

* *i. e.* a telescope carried on an axis which is parallel to the axis of the earth, and hence sometimes called a *parallactic* instrument.

Each of the large exterior divided heads of Fig 1 is fixed upon a screw, which by its revolution carries one of the spider-web lines B *b*, C *c*, Fig. 2, in a parallel direction The small milled-head screw, which works on an interior toothed wheel, turns the whole system round in the direction of the arrow, or reversely The observation is made thus · the telescope being set upon the stars, and clamped in declination, is kept upon them by working a handle and Hook's joint; the small milled-head is turned round until the spider-line, A *a*, is parallel to the line joining the centres of the stars, which with a little care it may be made to thread at the same moment. The reading of the verniers*, if they have been previously adjusted, will now point out the *angle of position* of the stars Now since A *a* is in the direction of the stars, the lines B *b* and C *c* are perpendicular to that direction; one of them, as B *b*, is made to bisect one of the stars by moving the instrument by the handle and Hook's joint, while the other, C *c*, by turning the divided head which carries it, is made to bisect the other star The revolutions and parts of the divided head between the coincidence of the two wires and the bisection of the two stars will, with a knowledge of the scale†, give the distance.

Fig. 3. Sir W Herschel.

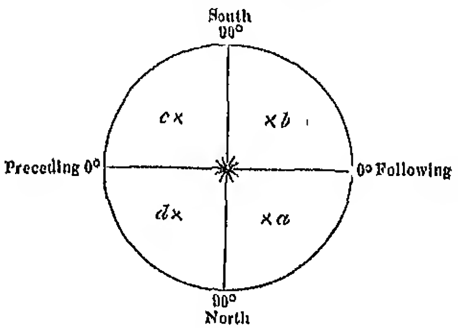
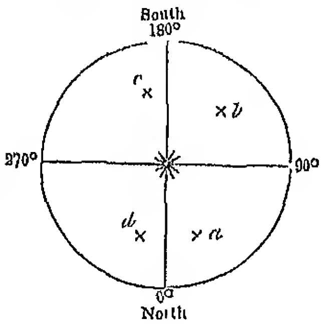


Fig 4 Sir J. Herschel.



* In the micrometer here represented, which is graduated according to Sir J Herschel's recommendation, the divisions run from 0° to 360°, and the verniers read 90° and 270°, when the star, by its own motion, runs along the fixed wire. For Sir William's nomenclature the circle should be divided into four quadrants, and the readings of the verniers be each 0 when the star runs along the fixed wire To prevent mistakes, a diagram of the stars should always be made at the time of observation.

† To obtain the value of the scale of the micrometer, set the two moveable wires apart a certain number of revolutions, and place them in the direction of the meridian. Ob-

Some modifications in this process have lately been introdu which we will now briefly mention Sir William Herschel desci the position of the small star (see fig 3, which shows the app ance of a double star in an inverting telescope), as being to north or south, preceding or following the principal star. angles are reckoned from the parallel of daily motion, from (the north or south point, each of which is marked 90°. In figure, *a*, is a north following star; *b*, south following; *c*, south ceding, *d*, north preceding, and the micrometers constructed this nomenclature are divided into four quadrants. As this mod reckoning is complex, and at times leads to errors, Sir J. Hersc proposed in vol iv. of the *Royal Astron Soc Mem*, p. 333, commence the reading of the angle from the meridian at the n point, and to continue it round in the direction *n f s p n* (north, lowing, south, preceding, north,) from 0° to 360°. so that 1° responds to 89° *n f*, 91° to 1° *s f*, 181° to 89° *s p*, 271° to 1° *n p* This proposition has been universally adopted, at least in country (see Fig. 4, which is the apparent field of view gradu according to Sir John Herschel. In this figure the angle of posit for *a* is about 30°; for *b*, 135°; for *c*, 190°, for *d*, 330°). Anot simplification has been pointed out, we believe by Sir John H schel (it has certainly been adopted successfully): *viz.*, to supp the fixed spider-line A *a* (Fig 2) altogether, and to use the li B *b*, C *c*, placed near each other, for determining the angle of po tion The micrometer is then adjusted when a star travels al one of the wires, the instrument being at rest, and the verniers sl 90° and 270° After this verification is made, or what is be the error ascertained, to be hereafter applied as a correction,

serve the transits of several stars of known declination over the wires; then multipl each interval of seconds of time by 15 cosine of star's declination, and taking the m you have the seconds of space which correspond to a known number of revolution the screw.

* If *h* be the angle of position in Sir J. Herschel's system, and H that accordir Sir William's, then

$$h = 90 - H \text{ in the north following quadrant}$$
$$= 90 + H \quad \text{,, south} \quad \text{,,}$$
$$= 270 - H \text{ in the south preceding quadrant}$$
$$= 270 + H \quad \text{,, north} \quad \text{,,}$$

wires are turned round by the small milled-head screw until the stars are either *threaded* upon one of the wires, or, being between them, are judged to be parallel to them. The verniers are now read off for the angle of position. This observation is repeated until the result is satisfactory, and then the verniers are turned by the milled-head through 90°, when the wires are in the proper position for taking measures of distance. In this way the danger of the wires B *b*, C *c* touching A *a*, technically called *fiddling*, is avoided, as well as the indistinctness which with high powers will be found in one of three wires all at different distances* from the eye-glass. There is, besides, the advantage of measuring the distance a little more certainly in the proper direction, and the operation is performed in less time. In measuring the distance of two stars, after the wire B *b* has been placed upon one of the stars, the larger for instance, and C *c* on the smaller, it is better to move the whole instrument by the handle and Hook's joint until B *b* is placed on the smaller, and to move C *c* by its divided head to a position C′*c*′ (see Fig. 2) to bisect the larger. The revolutions and parts described by the divided head now give twice the distance of the two stars, and any uncertainty about the zero reading is eliminated.† If there be any doubt about the truth of the screws, C′*c*′ may now be considered to be the fixed wire, and B *b* the moveable one, and thus the measure may be repeated‡, in different parts of each screw.

Hitherto we have spoken as if the whole instrument was to be moved by the observer, by hand, so as to counteract the effect of the

* This may be obviated by pushing in or pulling out the eye-piece between the two measures of position and distance, but besides the trouble and loss of time, there is some risk, if the eye-piece move stiffly, of deranging the apparatus.

† This zero is thus determined. The wire C *c* is brought to touch B *b* first on one side and then on the other, and the mean of the readings of the micrometer head in each position is the reading when the wires coincide. The difference of this reading from 0 is added to or subtracted from all the subsequent readings of C *c*, according as the zero reading is backwards from 0 or forwards, in the order of the graduation, just as the index-error of a sextant. In this method, B *b* is a fixed wire. In the method recommended in the text, (it is due to Sir J. Herschel,) one of the readings of the micrometer is to be *subtracted* from the other, but this will cause no embarrassment to an intelligent observer.

‡ The Germans call this micrometer the "repeating thread micrometer."

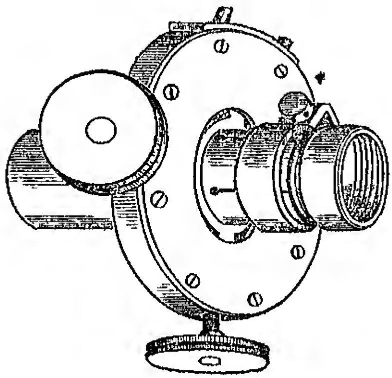
diurnal motion. Within the last few years, since the introduction of large refracting telescopes, clock-work has been successfully employed, especially by the celebrated Fraunhofer. The essential quality of a clock for carrying an equatorially mounted telescope, is that it should move smoothly, and not be affected *suddenly* by any alteration of friction, &c Fraunhofer's clock is a train of wheels driving an upright spindle on which two small balls are hung. These expand outwards by the rotatory motion of the spindle until they rub against a conical surface above them something like an umbrella, the friction against which destroys the superabundant power of the clock, and brings it to a uniform motion. There is a contrivance for raising or lowering the point on which the spindle turns, and so regulating the clock to the velocity required. This clock answers very well, and is neither cumbrous nor expensive Another clock, on a similar principle, but on a larger scale and with more powerful action, has been constructed in this country by Messrs Troughton and Simms. The upright spindle in this case carries a regular governor, like that attached to steam-engines, which by a double lever presses a powerful break on a wheel attached to one of the arbors of the clock when the balls are expanded to the proper distance*. In Fraunhofer's equatorials, the bisection of a star is effected by continual alterations of the rate of the clock, by means of a long handle, which is exceedingly inconvenient. In the apparatus of Messrs. Troughton and Simms, the micrometer is fitted on a *slipping-piece* (see Fig. 5) which again fixes on the end of the telescope.

By the two milled-head screws, a very delicate motion can be given to the micrometer in any required direction, without rotatory motion, so that the bisections which were heretofore performed by moving the whole instrument, are now accomplished much more satisfactorily by touching a screw close to the observer's hands. It is desirable to have the slipping-piece and micrometer as light as is consistent with necessary strength, and the screws of the slipping-

* For a description and figure of this clock, see the *Abstracts of the Proceedings of the Royal Astronomical Society*, vol. iii. No. 6 It was subsequently attached to one of the largest equatorials hitherto constructed, which it carried with great truth and perfect smoothness. It is now in the possession of Charles Holford, Esq, F R.A S.

piece should be very smooth and fine When the apparatus is properly made, and the clock correctly rated, the observation of such

Fig 5. Slipping-Piece.



double stars as the telescope will separate, is quite as easy as the measurement of two dots on a sheet of paper The only difficulty left, is that of procuring a tangent screw to give motion to the instrument with sufficient accuracy

There are many minutiæ connected with this subject which it would be tedious to explain at length, though much of the convenience and comfort of observing depends on them. We will, however, mention one very elegant improvement by the Astronomer Royal in the construction of a splendid equatorial, lately presented by the Duke of Northumberland to the University of Cambridge. In this instrument, the hour circle, which is carried by clock-work, turns freely on the lower pivot of the polar axis, but can be clamped at pleasure to the bottom frame of the axis which carries the verniers or microscopes. If this hour circle be at first properly set, and the clock made to go sidereal time, it is evident that the verniers will show the right ascension of the star directly, without any arithmetical operation whatever

When the position-micrometer is used, it is absolutely *necessary* that the telescope should move without any shake or jar (which is, however, no difficulty since the introduction of clock-work), and it is *desirable* that the mounting should be firm enough to fix a star within a few minutes*. If these requisites are obtained, and the tube of the telescope be stiff enough to allow the observer to touch the screws of the slipping-piece and micrometer without shaking, the mounting is sufficient for the measurement of double stars. The difficulty in managing large instruments arises from the monstrous increase of the *moment of inertia*, (which is parried by the equable motion given by the clock,) and the tendency of the telescope and frame to twist when pressure is applied to a longer lever, *viz.*, at the eye end of the telescope.

Another instrument for measuring double stars, which requires less steadiness, has recently been most successfully used by Professor Bessel, of Konigsberg. This is a telescope of which the object glass is cut in two by a plane passing through the diameters of the lenses, and perpendicular to their surfaces. One half can slide by the side of the other, and as each half gives a complete image, a double star appears like four stars, which can be placed in a right line (this gives the angle of position), and at equal distances (which gives the distance). The observations made by Bessel with the heliometer, as it is called, are greatly superior in accuracy to any other observations hitherto published. As the operation of cutting an object glass in two is a somewhat hazardous one, and the images formed by it never so perfect as those by an undivided glass, it would perhaps be advisable to try what could be effected by dividing one of the lenses of an eye-piece, which would give double images, and might be applied to any telescope whatever.

Information on the subject of double stars and nebulæ must be gathered from various original memoirs. The following list contains those which are most remarkable:—

De Novis in Cœlo sidereo phænomenis Mannheim, 1779. (*Christian Mayer*.)

* Any considerable deviation or want of adjustment of the instrument will affect angles of position observed far from the meridian. It must, however, be very large to do any sensible injury; and if the flexure be nearly constant in the same position, it may be allowed for. For the adjustments of the equatorial, see a *Memoir* by M. Kriel, *Mem. Ast. Soc.*, vol. iv., p. 495, or the *Abstracts of the Memoirs*, vol. i., No. 29.

Phil. Trans., vol. lxxi., p. 492.—Account of measurements of position and distance, with a description of a position micrometer. (*W. Herschel.*)

——— vol. lxxii., p. 112.—A catalogue of double stars (269 in number). (*W. Herschel.*)

——— vol. lxxii., p. 163.—Description of lamp micrometer. (*W. Herschel.*)

——— vol. lxxv., p. 40.—Further catalogue of double stars (434). (*W. Herschel.*)

——— 1804, p. 353.—*Account of changes that have happened in the relative situation of double stars. (*W. Herschel.*)

Mem. Ast. Soc., vol. i., p. 166.—Catalogue of 145 new double stars. (*W. Herschel.*)

——— vol. iv., p. 165.—Catalogue of 195 double stars, taken from La Lande's Histoire Céleste.

Phil. Trans., 1824, Part 2.—Catalogue of 380 double stars. (*J. Herschel and South.*)

——— 1826, Part 1.†—Catalogue of 458 double stars, with a synoptical view. (*South.*)

Mem. of Ast. Soc., vol. ii., p. 459.—Observations made with a twenty feet reflecting telescope. Descriptions and approximate places of 321 double and triple stars. (*J. Herschel.*)

——— vol. iii., p. 47.—Continuation of the above (295 stars). (*J. Herschel.*)

——— vol. iii., p. 177.—Do. third series (384 stars). (*J. Herschel.*)

——— vol. iv., p. 331.—Do. fourth series (1236 stars). (*J. Herschel.*)

——— vol. iv., p. 1.—Do. fifth series, with remarks (2007 stars). (*J. Herschel.*)

These five series are not to be considered accurate measures. They are such double stars as were met with by Sir J. Herschel in his sweeps for nebulæ, &c.

Mem. Ast. Soc., vol. v., p. 13.—Micrometrical measures of 364 double stars, with a seven feet equatorial. (*J. Herschel.*)

* Said to be a continuation of a paper in the vol. for 1803, p. 339, where however no such paper appears.

† This paper contains many valuable notes and remarks by Sir J. Herschel.

Mem. Ast Soc., vol. v, p. 171*.—On the investigation of the orbits of double stars, being a supplement to a paper entitled 'Micrometrical Measures.' (*J. Herschel.*)

Mem Camb Phil. Soc., vol. iv, p 425.—Description of a machine for resolving by inspection certain important forms, &c, of transcendental equations. (*J. Herschel.*)

Mem Astron Soc, vol. vi., p 149.—Notice of the elliptic orbits of ξ Bootis, γ Virginis, η Coronæ (*J. Herschel*)

———— vol viii., p. 37.—Second series of micrometrical measurements. (*J. Herschel*)

———— vol. iii., p 257.—Approximate places of double stars in the southern hemisphere. (*Dunlop.*)

———— vol. v., p. 135—Observations of the triple star ζ Cancri (*Dawes*)

———— vol. v, p. 139.—Observations of double stars. (*Dawes.*)

———— vol. viii., p. 61.—Measurements of 121 double stars. (*Dawes.*)

Sir J Herschel is now at the Cape, measuring the double stars of the southern hemisphere, and noting the nebulæ.

Struve, Catalogus novus stellarum duplicium (3112 stars). Dorpat, 1827.

Astronomische Nachrichten, No. 240, vol. x., p. 392, contains observations of thirty-nine double stars by Bessel, with a comparison of his results with those of Struve These are probably the *best* results in distance yet published. Struve seems to have a constant error of about 0″·3 in his distances, which are too small. Further catalogues may be expected from Bessel and Struve.

NEBULÆ.

Connoissance des Tems, 1784.—100 nebulæ by Messier, 3 by Mechain.

Phil. Trans, vol. lxxvi., p. 457.—Catalogue of 1000 nebulæ and clusters. (*W. Herschel.*)

* This is a description of the easiest, as well as the most elegant and accurate manner of investigating the orbits of double stars, chiefly by a graphical method, which is applicable, and indeed has been applied to many physical questions. The following memoir is a sort of supplement to it. M. Savary and Professor Encke have solved the same problem geometrically, but not with equal practical success.

Phil. Trans, vol. lxxix., p 212.—Catalogue of a second thousand new nebulæ and clusters, with remarks on the construction of the heavens (*W Herschel*)

——— 1802, p 477.—Catalogue of 500 new nebulæ, nebulous stars, planetary nebulæ, clusters, with remarks on the construction of the heavens. (*W Herschel*)

——— 1811, p. 269.—Astronomical observations relating to the construction of the heavens, &c (*W Herschel*)

——— 1814, p 248.—Continuation of the last. (*W Herschel*)

Many most valuable memoirs, by Sir W Herschel, which it would be tedious and out of place to specify here, are to be found in the volumes of the Phil. Trans Such are his early views on the construction of the heavens—vol lxxiv., p 437; vol lxxv., p 213, 1795, p. 46, 1796, p. 166 On the comparative brightness of stars, &c—1796, p. 166, 1797, pp 142 and 293, 1799, p 121 On his telescopes and power of penetrating into space—1795, p 347; 1800, p 49; 1817, p. 302; 1818, p 429, &c It is hoped that a complete collection of Sir W. Herschel's Memoirs may be given to the public at no very distant period.

Phil Trans, 1828, p 113.—Nebulæ and clusters in the southern hemisphere. (*Dunlop.*)

Phil. Trans., 1833, Part 2, p. 359.—A catalogue of nebulæ, *J. Herschel.* This most important memoir is the result of a revision of the heavens, by Sir J. Herschel, with a similar instrument to that used by his immortal father On the return of Sir J. Herschel from the Cape of Good Hope, we may hope for a like account of the southern hemisphere, thus completing a statistical survey of the heavens at a given epoch. On looking over the list of the memoirs cited, it is obvious how entirely nebulæ and double stars may be considered as the acquisition and inheritance of the Herschels, and this notion will be much strengthened by a close examination of the substance of the memoirs Others may have measured and noted very laudably, but philosophical views and practical details are almost wholly due to them.

A LIST OF TEST OBJECTS

Principally Double Stars arranged in Classes for the trial of Telescopes in various respects as to light, distinctness &c By Sir J F W Herschel K G H &c &c

Inserted by permission of the Council of the Royal Astronomical Society

N B No Double Star is inserted in this list which has not been distinctly separated by the 20 foot Reflector or 7 foot Equatorial

Class A —Double Stars nearly equal

1st Division Large Stars

6th magnitude and upwards

Object	R A 1830 ±	N P D 1830 ±	Dist	Magnitudes	Remarks
	h m				
γ Arietis	1 43 0	71 33	9	4 = 4	
Castor	7 23 5	57 45	5	3 3+	
α Piscium	1 53 0	88 5	5	4 , 4	
ζ Aquarii	22 10 8	90 58	4	5 5	
μ Draconis	17 1 8	35 18	4	6 = 6	
Androm 37 (B)	23 50 7	57 13	4	6 = 6	
44 Boötis (H)	11 58 0	41 38	3	5 = 5	
ξ Ursæ	11 8 8	57 30	2	5 , 5+	
ζ Boötis	14 32 8	75 31	1	5 5	
γ Virginis	12 32 8	90 29	1½	4 = 4	

Class A —2nd Division *Small Stars 7 11th mag*

7th magnitudes.

Object	R A 1830 ±	N P D 1830 ±	Dist	Magnitudes	Remarks
Σ 2351	18 30 0	48 40	5	7 = 7	
Androm 23 (B)	23 43 4	53 4	4	7 = 7	
Σ 1910	14 50 1	80 0	4	7 = 7	
Σ 2047	2 13 3	22 22	3	7 = 7	
HN 132	1 23 5	72 22	3	7 = 7	
Coronæ 1 (B)	15 10 0	62 30	2	7 = 7	
Σ 1333	9 7 7	53 55	1½	7 = 7	
η Coronæ	15 16 1	60 4	1	7 , 7	The close star
80 Androm 11	0 45 6	07 10	½	7 = 7	
ι Arietis	2 49 4	69 28	½	7 , 7 8	
4 Aquarii Fl	20 42,1	96 17	¼	7 7 8	

8th magnitudes

Object	R A 1830 ±	N P D 1830 ±	Dist	Magnitudes	Remarks
Σ 182	1 44,5	29 34	4	8 8	
H II 52	3 20 1	56 20	4	8 = 8	
H I 60	0 51,9	86 59	4	8 = 8	
Σ 323	2 43 1	84 17	3	8 = 8	
Lyncis 157 B	9 9,0	51 5	2½	8 = 8	
Σ 2845	21 47,5	27 44	2½	8 = 8	
Σ 2701	20 28,7	78 33	2	8 = 8	
Σ 18	0 7,5	28 20	1½	8 = 8	
Σ 801	0 9,3	59 14	1½	8 = 8	
Σ 158	1 30,7	67 42	1	8 = 8	
Σ 1883	11 40,2	88 20	1	8 = 8	
Σ 115	1 12,2	32 46	¾	8 8	

Class A.—2nd *Division, continued.*

9th magnitudes

Object	R A 1830 ± h	m	N P.D 1830 ± °	′	Dist. ″	Magnitudes.	Remarks
Σ 4	0	0,9	82	31	5	9 = 9	
Σ 2747	20	55,7	53	0	4	9 = 9	
Σ 777	5	33,1	67	53	3	9 = 9	
Σ 1564	11	30,7	62	6	3	9 = 9	
h 550	14	19,8	53	58	2	9 = 9	
h 3074	21	40,6	92	38	1½	9 , 9	
Σ 1620	12	8,3	18	59	1	9 = 9	
Σ 2825	21	38,2	89	56	1	9 , 9	
Σ 2924	22	28,3	20	58	1	9 = 9	
Σ 1093	7	17,1	30	41	1	9 , 9	
Σ 2500	10	14,9	27	7	½	9 , 9	
10th magnitudes.							
h 1780	23	17,6	54	6	5	10 = 10	
h 416	7	8,8	66	59	4	10 = 10	
h 450	8	10,9	71	20	3	10 = 10	
h 1491	20	5,2	49	0	2½	10 = 10	
Σ 2005	22	18,8	75	43	2	10 = 10	
h 1637	20	26,8	105	52	1¾	10 = 10	
h 1305	19	19,6	53	12	1½	10 = 10	
Σ 1795	21	17,0	30	3	1½	10 = 10	
h 630	1	22,4	94	31	1½	10 = 10	
Σ 609	4	42,8	80	4	1½	10 = 10	
Σ 1033	7	0,9	37	10	1	10 = 10	
Σ 1504	10	54,3	85	27	1	10 = 10	
11th magnitudes.							
h 1104	1	56,2	22	0	5	11 = 11	
h 1384	19	13,0	94	10	4	11 = 11	
h 1860	23	0,0	34	44	4	11 = 11	
h 1036	0	25,5	48	3	3	11 = 11	
h 686	16	27,4	54	37	3	11 = 11	
h 1770	22	20,7	56	19	3	11 = 11	
h 1895	23	20,0	34	22	3	11 = 11	
h 1145	4	17,3	20	54	2½	11 = 11	
h 98	8	28,7	91	50	2 :	11 = 11	
h 1032	17	33,5	65	4	1¾	11 = 11	
h 1038	0	20,6	27	13	1½	11 = 11	
h 1855	23	4,0	45	21	1½	11 = 11	
h 1838	22	52,1	23	49	1	11 = 11	

Class A.—3rd *Division Minute Stars (below 11th magnitude).*

Object	R A 1830 ± h	m	N P.D 1830 ± °	′	Dist. ″	Magnitudes.	Remarks
12th magnitudes							
h 300	6	42,3	93	4	3	12 = 12	
h 545	14	11,5	50	35	3	12 = 12	
h 1302	19	17,1	43	53	3	12 = 12	
h 701	8	25,4	56	51	2½	12 = 12	
h 1417	19	28,1	106	13	2	12 = 12	
h 1300	17	27,5	94	34	2	12 = 12	The small star double.
13th magnitudes.							
h 685	4	40,6	90	13	4	13 = 13	
h 70	7	45,3	78	15	3 :	13 = 13	
h 1914	23	44,3	35	8	2	13 = 13	
h 1704	21	48,2	62	54	1½	13 = 13	

Object	R A 1830 ±		N P D 1830 ±		Dist	Magnitudes	Remarks
Class A.—3rd Division, continued. Minute Stars (below 11th mag.) 14th magnitudes							
	h	m	°	′	″		
h 1150 . . .	3	27,4	20	49	4	14 = 11	Follows a larger double star in same field.
h 1360 . . .	18	54,7	53	35	3	14 = 14	
h 1265 . . .	14	52,7	82	58	3	14 , 14	
β² Equulei . .	20	14,3	83	54	2	14 , 15	The small companion of β is double.
Below 14th magnitudes.							
h. 1157 . . .	5	26,7	95	30	5	. . . .	The small companion of β¹ & β³ *Capricorni* is a close dble. star.
h. 2948 . .	20	11,5	105	18	3	. . . .	
h 1248 . . .	14	7,5	81	52	2	. . . .	
h. 709 . . .	5	36,4	61	5	2	. . .	
h 649 . .	2	14,3	81	10	1½	. . . .	
h. 836 . . .	10	36,2	61	4	1½	. . . .	
Class B.—Moderately unequal Stars. 1st Division: Large Stars							
ξ Cephei . . .	21	58,5	26	14	6	4·5 , 7	
μ Cygni .	21	36,2	62	1	6	5 , 6	
ι Trianguli . .	2	2,4	60	31	4	5 , 8	Yellow and blue
γ Leonis . .	10	10,4	69	16	3	2·3 , 4	
δ Serpentis . .	15	26,4	73	53	3	5 , 6	
38 Lyncis Fl .	9	7,8	52	28	3	5 , 8	
ι Cassiopeiæ	2	15,0	23	22	2	5 , 8	
ζ Cancri . . .	8	2,1	71	50	1½	6 , 7	Triple. The close star.
λ Ophiuchi . .	16	22,1	87	38	1	5 , 7	
Class B.—2nd Division. Small Stars.							
59 Serpentis Fl	18	18,3	89	55	4	7 , 9	
Ursæ 284 B . .	11	28,9	24	43	3	7 , 9	
Σ. 517 . . .	4	7,2	89	59	3	8 ,10	
Σ 2910 . . .	22	37,0	18	10	3	10 ,12	
10 Arietis Fl .	1	53,8	64	55	2	7 , 8	
Cygni 280 B .	20	52,9	40	13	2	7 , 8	
32 Orionis Fl. .	5	21,4	84	12	1½	8 , 9	
Σ 1858 .	14	26,6	53	41	1½	8 , 9	
Canis. Min 31 B	7	30,8	84	22	1½	8 , 9	
h 1018 . . .	0	11,6	23	16	1½	10 ,11	
Σ 1630 . . .	12	10,5	32	40	1½	10 ,11	
σ Coronæ . .	16	7,5	55	40	1½	7·8, 9	The close star.
μ² Bootis . . .	15	18,0	52	4	1	8 , 9·10	The small companion of μ.
Σ 770 . . .	5	31,4	70	52	1	9 ,11	
h. 2562 . . .	11	1,2	57	55	1	9 ,12	
Class C.—Very unequal Stars. 1st Division: Small Star conspicuous.							
η Cassiopeiæ .	0	38,5	33	7	12	4 , 8	Small star, purple.
α Herculis . .	17	6,7	75	24	5	3 , 8	
ζ Orionis .	5	32,1	92	4	3	2 , 7	
ε Bootis .	14	37,4	62	11	3	3 , 8	
ι Draconis . .	19	48,7	20	11	3	4 , 8	Small ✗. No 1 conspicuous in an *un*illumined field

Class C.—2nd Division: Small Star not conspicuous.							
Object	R A 1830 ±		N P D 1830 ±		Dist	Magnitudes.	Remarks.
	h	m	°	′	″		
ζ Sagittæ	19	41,2	71	17	10	4 , 9 10	
κ Pegasi	21	36,9	65	8	9	4 , 10	
θ Virginis	13	0,9	94	36	7	5 , 10	Pretty conspicuous, with illuminated field.
ι Leonis	11	14,8	77	31	3	4 , 9	
ε Hydræ	8	37,6	82	56	3	4 , 10	
γ Ceti	2	34,2	87	31	3	3 , 9	
h 3003	20	43,0	114	25	3	6 , 11	
δ Cygni	19	39,5	45	17	2	3 , 10	
h 1051	0	35,6	66	13	1½	10 , 14	

Class D.—Extremely unequal Stars.							
Rigel	5	6,3	98	25	9	1 , 9	
Polaris	0	59,3	1	36	15	2 , 10	
α Lyræ	18	31,2	51	23	45	1 , 11	
λ Geminor	7	8,0	73	9	15	4 , 11	
ν Ursæ	11	9,3	55	59	10	3 , 11	
δ Equulei	21	6,0	80	42	30	4 , 12	
τ Orionis	5	9,3	97	2	18	4 , 12	Triple, (A B)
ξ Pegasi	22	38,2	78	42	15	5 , 12	Triple The distant *
Σ. 5	0	1,1	79	50	12	6 , 12	
ζ Persei	3	43,5	58	38	10	3 , 12	Triple, The near star.
φ Piscium	1	4,5	60	19	8	5 , 12	
Σ. 320	2	43,1	11	16	6	6 , 12	
Σ 2587	19	43,0	86	20	5	7 , 12	
Σ 2790	21	14,4	32	6	3	7 , 12	
η Coronæ	15	16,1	59	4	40	6 , 13	Triple. The dist star.
σ Coronæ	16	7,5	55	40	40	7 , 13	Quadruple. The more distant *
ι Ursæ	8	47,6	41	18	12	3·4, 13	
h 693	5	0,7	82	3	5	7 , 13	
γ Hydræ	11	16,3	106	41	3	4 , 13	
τ Orionis	5	9,3	97	2	18	4 , 14	Triple. (A.C.)
h. 2603	12	5,4	76	51	15	7 , 14	
μ Sagittarii	18	3,6	111	7	12	3·4, 14	Quadruple. The close *
12 Ceti Fl.	0	21,1	94	54	8	7 , 14	
κ Geminor	7	34,2	65	12	5	4 , 14	
φ Virginis	14	19,5	91	28	4	5 , 14	
β Aquarii	21	22,6	96	10	20	3 , 15	
h. 2714	14	14,5	109	1	15	7 8, 15	
h. 2666	13	29,4	103	58	8	9 , 15	
32 Leon Min. Fl	10	23,3	48	43	25	5 , 16	
τ Bootis	13	39,0	71	40	20	4 , 16	
33 Leonis Fl.	10	22,8	66	45	20	6 , 16	
31 Cygni Fl.	20	8,3	43	46	20	4 , 16	
σ Coronæ	16	7,5	55	40	20	[illegible], 16	Quadruple. The intermediate *

Class D.—*Extremely unequalled Stars, continued.*

Object	R A 1830 ±		N P D 1830 ±		Dist	Magnitudes	Remarks.
	h	m	°	'	"		
Σ. 324 . . .	2	44,9	43	32	{12 / 8	8 , {16... / 16...	} Triple.
ξ Pegasi . .	22	38,0	78	43	11	5 , 16 .	{ Triple. The close star.
ω² Cancri . . .	8	49,0	77	28	10	4·5, 16...	
h 3032 . . .	21	21,0	85	51	10	8 , 16...	
h. 338 . . .	3	44,3	92	53	10	5 , 10 .	
h. 2732 . . .	14	26,4	44	9	9	9 , 16...	
h 2577 . . .	11	25,5	61	18	8	9 , 16...	
α² Capricorni .	20	8,7	103	4	8	3 , 16 ..	
94 Ceti Fl. . .	3	4,0	91	50	6	5 , 16..	
30 Pegasi Fl. .	22	11,8	85	4	{ 6 / 4	5 , {16 . / 16...	} Triple.
h 333 . . .	3	13,9	57	4	3	6 , 16...	

N B Among this class D are some very difficult, and some comparatively easy objects, but they require re examination to arrange them in their proper order.

Class E —Resolvable Clusters of Stars

For trying the space penetrating powers of Telescopes.

Object	h	m	°	'	Remarks
13 Messier . .	16	35,7	53	12	Between η and ξ Herculis.
5 Messier . .	15	9,9	87	16	
3 Messier . .	13	34,3	60	46	
2 Messier . .	21	24,6	91	34	
15 Messier .	21	21,7	78	34	
53 Messier . .	13	4,6	70	56	
28 Messier . .	18	14,0	114	56	
10 Messier . .	16	48,2	93	50	
9 Messier .	17	9,1	108	18	
19 Messier . .	16	52,1	116	0	
22 Messier . .	18	26,0	114	1	
I. 103 . .	20	26,9	83	10	
h Nova . . .	15	29,1	83	27	A faint object.
I 70 . . .	14	20,7	95	12	
Messier 46 .	7	34,0	104	25	{ Has a planetary nebula (IV 39) within it.

Class F —Remarkable Nebulæ

Not resolvable into Stars by Telescopes of any ordinary power, but presenting very different appearances in Telescopes of different degrees of optical capacity.

Object	h	m	°	'	Remarks
Nebula in Orion	5	27,2	95	32	
Messier 51 . .	13	22,6	41	55	
Messier 27 .	19	52,2	67	44	
Messier 17 . .	18	10 8	106	15	
Messier 60 . .	12	35,1	77	31	A double nebula.
IV 41 (H) . .	17	52,0	113	1	
V. 15 . . .	20	38,9	59	53	Passes through k Cygni.
V. 19 . .	2	12,0	48	25	A faint object.
Messier 64 . .	12	48,4	67	23	
Messier 57 . .	18	48,0	57	10	The annular nebula in Lyra.

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